CHAPTER 4

STEAM HEATING SYSTEMS

4-1. General.

A steam heating system consists of the following elements: a steam source; supply piping to carry the steam from the source to the heating equipment; heating equipment, such as radiators located in areas to be heated; and return piping to carry the condensate from the heating equipment back to the steam source. Steam heating systems are classified according to piping arrangement and method of returning the condensate to the boiler. The successful operation of a steam heating system requires the generation of steam at maximum efficiency and in sufficient quantity to equalize building heat losses, proper delivery of the steam to the heating terminal, expelling entrapped air, and returning all condensate, to the boiler rapidly. Steam cannot enter a space filled with air or water at a pressure equal to the steam pressure. Therefore, it is important to eliminate air and to remove water from the distribution system. All hot pipe lines exposed to contact by personnel must be properly insulated or guarded.

Section I. DESCRIPTION OF SYSTEMS

4-2. General.

Steam heating systems are classified according to the method of returning the condensate to the boiler, whether by gravity or by mechanical means. In the gravity system, the condensate is returned because of a static head of water in the return pipes. In this type of system all radiation must be above the boiler water line. In the mechanical system, the condensate flows by gravity to a receiver and is then forced into the boiler under pressure. The main difference between the mechanical and the gravity systems is that radiation in the mechanical system can be located below the boiler water line as long as there is a low spot to which the condensate can be drained and from which it can be pumped to the boiler, feed water heater, or surge tank.

4-3. Gravity one-pipe air vent system.

The gravity one-pipe air vent system was one of the earliest types in use. Because the condensate is returned to the boiler by gravity, this system is usually confined to a single building. Steam is supplied by the boiler and is distributed through a single piping system to radiators as shown in figure 4-1. Return of the condensate is dependent on the hydrostatic head. Radiators are equipped with an inlet valve and an air valve. The air valve permits venting of air from the radiators and displacement by steam. Condensate is drained from the radiators through the same pipe which supplies steam.

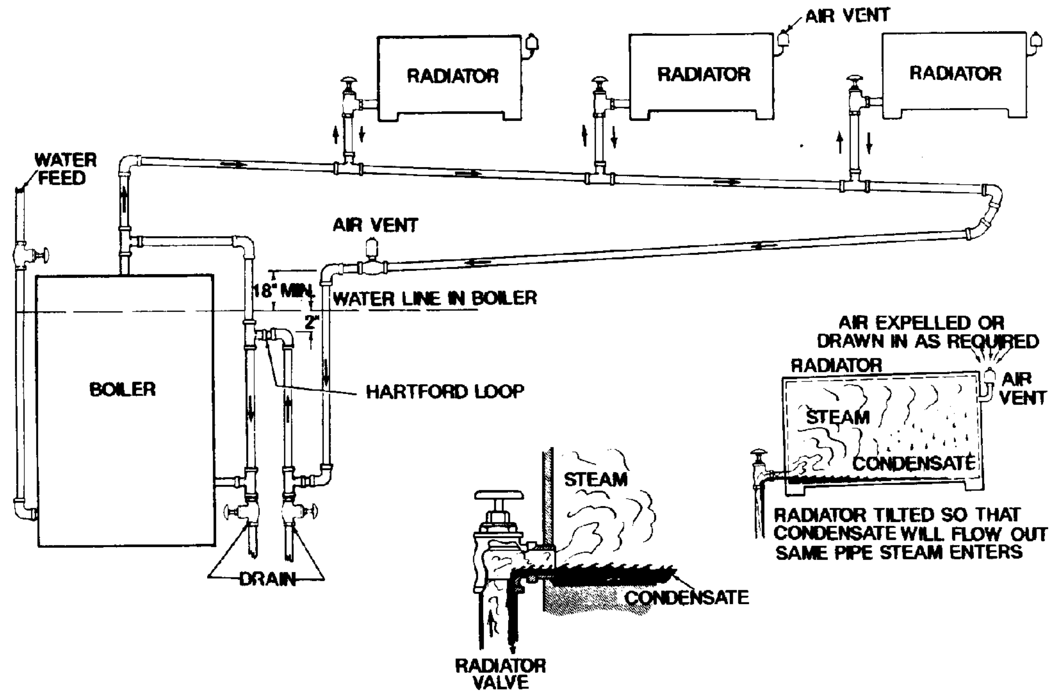


Figure 4-1. Gravity one-pipe vent system.

a. Controls. Appropriate controls for this system include a barometric draft control for boiler pressure control, or a pressure stat which controls a motor which operates the damper. Direct control of steam flow by use of mechanically operated steam valves is generally avoided due to difficulties in removing condensate after shut-off, and also due to the usual fluctuating steam pressure and flow characteristics of the gravity system. The gravity distribution system includes the boiler, radiators, piping, angle radiator valves of the on-off type as shown in figure 4-2, automatic air vent as shown in figure 4-3, and a barometric draft control as shown in figure 4-4.

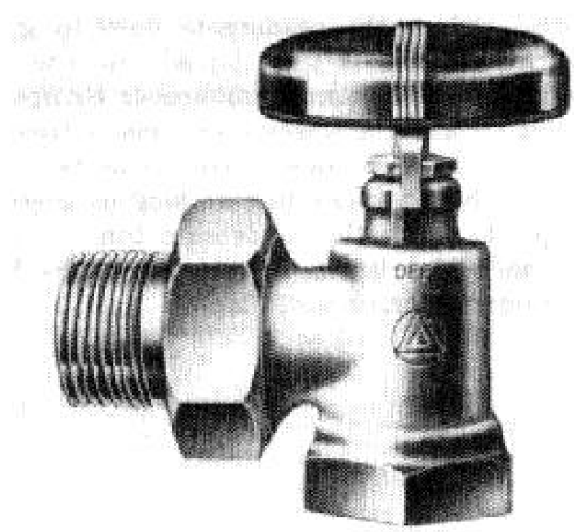


Figure 4-2. Angle radiator valve.

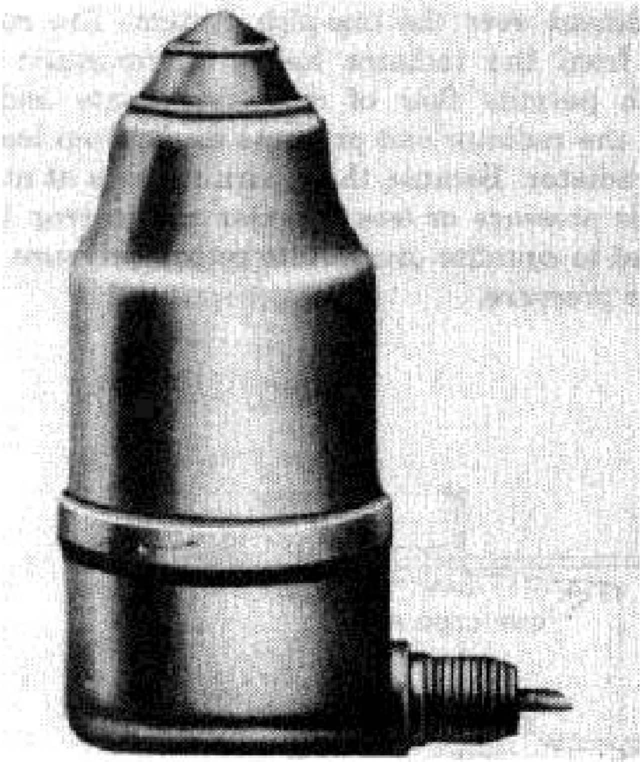


Figure 4-3. Automatic air vent.

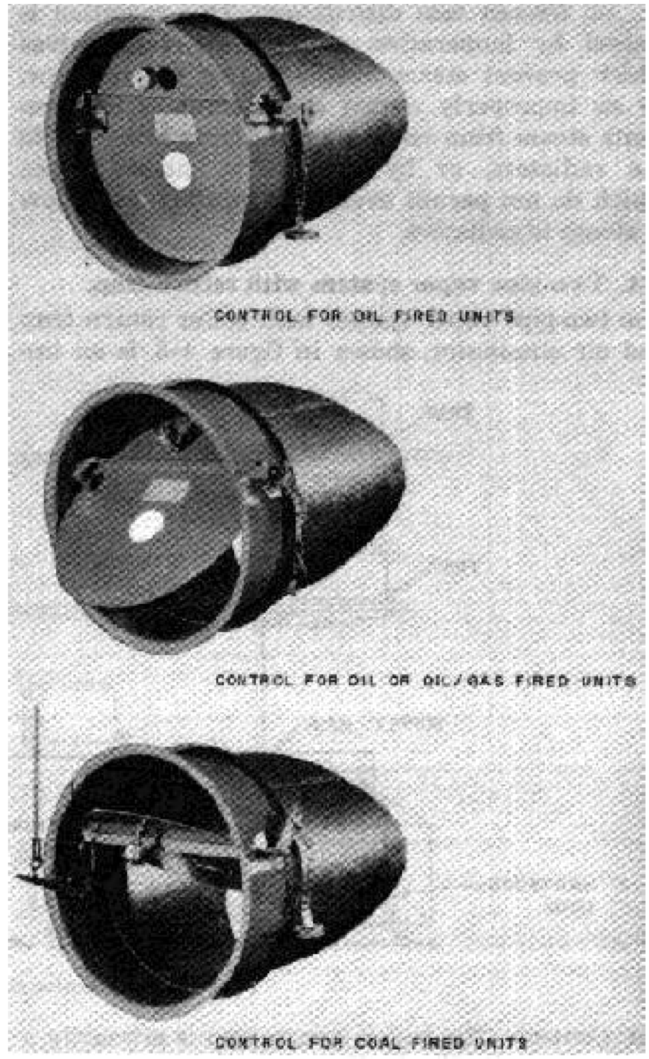


Figure 4-4. Barometric draft control.

b. Typical operating problems.

(1) *Radiator heat failure.* This is caused by air binding as a result of plugged or defective air vents, or by water logging due to insufficient radiator pitch (toward valve) or to partially closed radiator valves which permit trapping of condensate by the partial vacuum created.

(2) *Excessive noise.* This is caused by air vent failure and air binding of mains, insufficient radiator pitch resulting in entrapment of water, plugged or partially plugged wet return mains causing condensate to back up into steam mains, or improper pitch of mains and radiator branches.

(3) *Fluctuating water line.* This is caused by excessive pressure drop in long mains and insufficient head between the end of the main and the boiler water line to overcome the pressure drop. Grease or oil in the boiler water will also cause a fluctuating water line.

(4) *Uneven heat distribution.* This condition is caused by inoperative radiator air vent valves which prevent steam from entering the radiator, by an improperly vented steam main which prevents steam from reaching the piping branches to the radiators, or by improperly pitched pipes which do not permit even and uninterrupted flow of steam to radiators.

4-4. Two-pipe vapor system with return trap.

The two-pipe vapor system with boiler return trap and air eliminator, shown in figure 4-5, is an improvement over the one-pipe system. The return line from the radiator has a thermostatic trap which permits flow of only condensate and air from the radiator and prevents steam from leaving the radiator. Because the return main is at atmospheric pressure or less, a boiler return trap is installed to equalize condensate return pressure with boiler pressure.

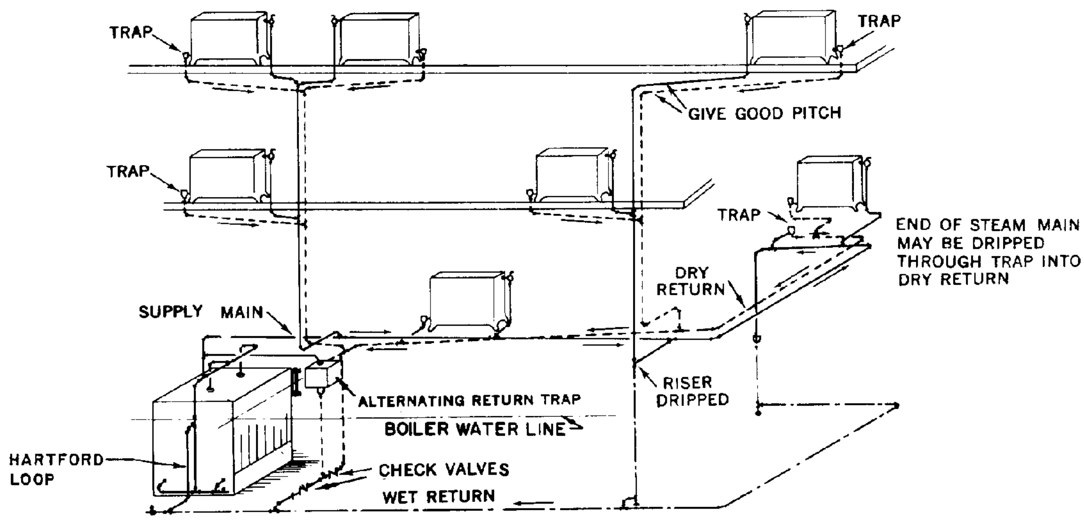


Figure 4-5. Two-pipe vapor system with return trap.

a. Controls. The boiler return trap is primarily a double valved float mechanism which permits equalization of boiler pressure and pressure within the return trap. The boiler return trap is installed on a vertical pipe in the return system adjacent to the boiler. The return trap has a valved steam connection to the boiler header and a vent connection to an air eliminator. Condensate rises into the return trap when the boiler is under pressure; the float-actuated vent valve is open during this part of the cycle. When condensate reaches the trip level of the trap, which is always below the bottom of the dry return, the float actuated valves reverse. The vent closes and the steam valve opens. This equalizes pressure above the condensate in the float trap with that of the boiler and causes the condensate in the trap to flow into the boiler. When low level is reached, the float actuated steam and vent valves again reverse. The steam valve closes and vent valve opens, relieves the pressure in the trap, and again permits the condensate from the system to rise into the return trap. This system is usually air tight and can be operated at subatmospheric pressures as low as 15 inches to 20 inches of water vacuum. This system is not used with unit heaters or blast coils which cause the condensate to be returned in slugs and the rate to be variable. Appropriate controls for this type of system are similar to those for gravity systems.

b. Typical operating problems.

(1) *Radiator heat failure.* This is caused by plugged or defective main air vents and by radiators waterlogged due to insufficient radiator pitch toward return connection. Radiator heat failure is also caused by clogged radiator traps and center air binding due to steam entry from both the return and supply ends if the trap is leaking because of failure of the thermal element.

(2) *System heat failure.* This is caused by clogged or defective air eliminators or improper operation of return traps. Return traps must be set level and have leveling tabs for proper installation. Return trap floats usually actuate the valves through a system of balanced weight arms which

may develop incorrect adjustment. The two check valves at the base of the return trap must be in good condition and the flow must be directed toward the boiler. The air eliminator and vent valve mechanism must be cleaned periodically to assure free action. The system may bind if excessive trap leakage occurs.

(3) *Air eliminator failure.* Water spurt from the air eliminator is caused by defective return trap operation or by a clogged connection to boiler.

(4) *Water line failure or fluctuation.* This is caused by boiler pressure beyond the limit of the trap, improper adjustment of the return trap, or boiler water contaminated with oil or grease.

4-5. Two-pipe vapor system with condensate pump.

The two-pipe vapor system with condensate pump is similar to the two-pipe vapor system with air eliminator return trap, except that the condensate is returned to the boiler by a power driven centrifugal pump instead of a return trap. The system includes a separate main, radiators fed at the top, and a return system with thermostatically trapped outlets at the bottom of the radiators opposite the feed end. The return main terminates at the receiver of the condensate pump and all air in the system is vented through a vent on the receiver. With use of a condensate pump, all returns to the pump are dry and radiators may be located below the boiler water line; this is not possible in the systems previously described. Ends of steam mains are dripped and vented into the dry return main through combination float and thermostat (F&T) traps. The two-pipe vapor system with condensate pump is frequently adapted to relatively large installations, particularly when unit heaters or blast coils are used and is probably the most practical and trouble free system. In addition to the boiler pressure controls, thermostatically controlled radiator valves or zone control valves may be used, since the return system is considered to be at atmospheric or lower pressure. This permits gravity flow of condensate to the pump receiver.

a. Controls. The condensate pump is normally controlled by a float activated switch located either in the condensate receiver or in a pipe located at the boiler waterline.

(1) *Receiver mounted float switch.* When the condensate from the system fills the receiver to a predetermined high level, the pump starts and, in turn, stops when a predetermined low level in the receiver is reached. Water between the two levels is discharged to the boiler. In this system, there is an initial lag in return of condensate. The boiler waterline lowers until the system has filled with steam and the return flow of condensate equals the rate of steam generation. It is therefore necessary to start a cold system with a slightly higher waterline to provide for flow of condensate in the return system and storage of condensate in the receiver. The high and low levels of the pump float valve setting should be set with adequate difference to eliminate frequent pump cycling. The settings should, however, be close enough so that the condensate discharge will not be large enough to cause excessive changes in normal boiler water level. Make-up water to this installation is supplied by manual feed or through automatic water feeders. Automatic water feeders should be set at the minimum safe boiler water level to eliminate unnecessary feed at low periods of the pump operating cycle. This pump control cycle is considered most satisfactory and results in little difficulty of operation.

(2) *Waterline mounted float switch.* With this control method the float switch is mounted in a separate chamber with pipe connections above and below the boiler water line. Since the pump may start at periods when the pump receiver is not filled, a float controlled make-up water valve is connected to the pump receiver to maintain a minimum water level in the receiver. This arrangement maintains a water level which does not vary too much and eliminates the lag of condensate feed described above. Operating difficulties encountered with this type of control usually more than offset the advantages. The float switch located on the boiler water line is a source of mechanical difficulty because of its small operating level range. If the water line control is out of cycle with the condensate return from the system, considerable make-up is used and condensate is wasted through the pump vent or overflow, unless there is surplus storage space in the receiver. The float operated receiver make-up valve is a source of unnecessary make-up of raw water to the receiver. This pump control system is suited only for systems which do not return all of the condensate to the boiler. This would include isolated buildings for which return is not practical or economical or installations where open steam jets are used, such as for dishwashers and steam tables.

b. Typical operating problems.

(1) *Radiator heat failure.* This is caused by inoperative traps or improper radiator pitch.

(2) *System failure.* This is caused by clogged or closed air vents at the pump receiver, by flooding of the return due to improper cut-in of the pump or by lack of pump capacity. Steam or air binding of the system caused by leaking traps may also occur.

(3) *Overflow from receiver vent.* This is caused by improper pump cut-in, inadequate pump capacity, clogged discharge piping or failure of the check valve on the pump discharge pipe. Failure of the check valve on the discharge side of the boiler feed pump permits flow of the boiler water through the pump and then to the receiver. The pump must then return the leakage to the boiler and this might be beyond the capacity of the pump. Hot condensate or hot boiler water back-up may cause vapor lock of centrifugal pumps and the pump will fail to discharge to the boiler. Overflow will occur in pumps in which float controlled make-up valves feeding the receiver are defective. This will cause excessive make-up water feed and flooding of the system.

(4) *Air returning to receiver tank and heating system.* It is advisable to provide a ball check or a vacuum vent for the air vent from the receiving tank. This type of vent permits discharge of air from the system and prevents return of air to the receiving tank and heating system. A vacuum of from 1 to 5 inches water gauge can be created if the system is tight.

4-6. Two-pipe vacuum system with vacuum pump.

The two-pipe vacuum system with vacuum pump shown in figure 4-6 is similar to the two-pipe vapor system with condensate pump. The piping system includes separate steam and return mains. Steam is supplied at the top of the radiators and condensate and air is discharged at the bottom of the opposite end of the radiator through a thermostatic trap. All returns are dry and terminate at the vacuum pump. The vacuum pump is usually motor driven, although low pressure steam turbines are sometimes used. The vacuum pump returns condensate to the boiler and maintains a vacuum or sub-atmospheric pressure in the return system. The maintenance of a vacuum in the return system (3 to 10 inches water gauge) enables almost instantaneous filling of heating units at low steam pressure (0 to 2 psig) since air removal is not dependent on steam pressure. This system is used in all types of buildings and offers a definite advantage for operation of indirect radiation units, heating coils and ventilating units, and for other units for which close automatic control is required. Quick filling of steam elements for this system is obtained since steam spaces are under vacuum during periods of shut-off. Vacuum pumps are two general designs, positive displacement and centrifugal type. These are shown in figures 4-7 and 4-8. Both types have a centifugal pump to return water to the boiler. The vacuum pump withdraws air and water from the system, separates air from water, expels air to the atmosphere and pumps water back to the boiler. Usually the vacuum pump is equipped with a float switch as well as a vacuum switch and can be operated as a condensate pump unit. The float switch should be used only when the vacuum system is defective and then only until defects can be repaired or corrected.

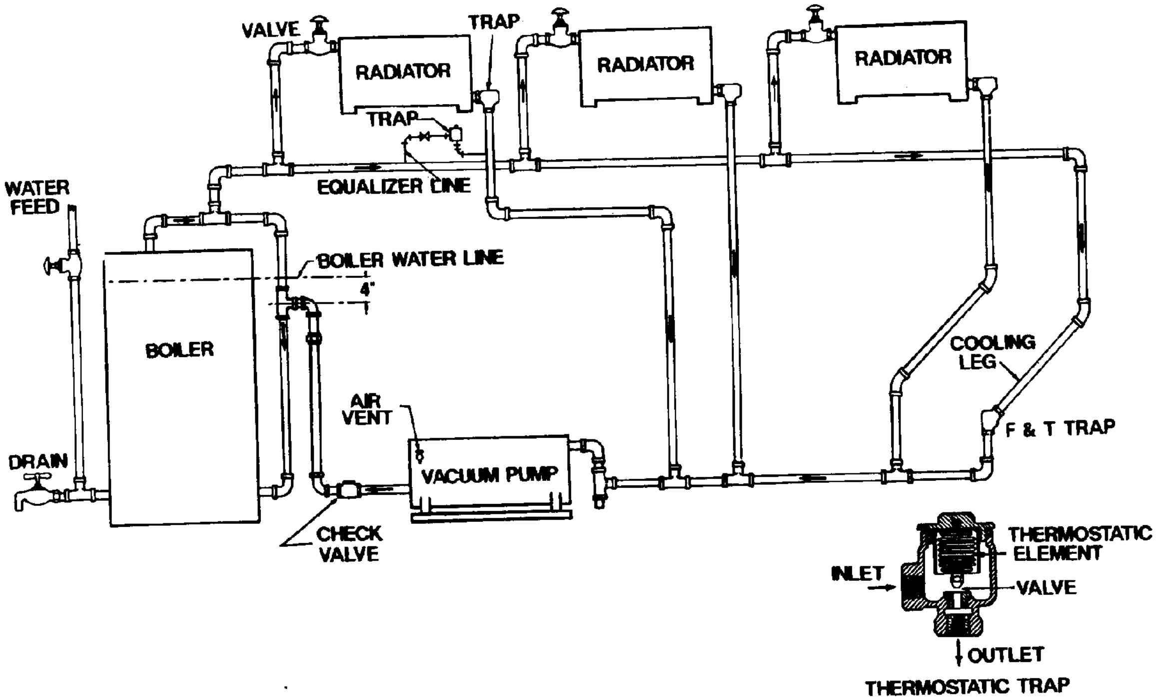


Figure 4-6. Two-pipe vacuum system with vacuum pump.

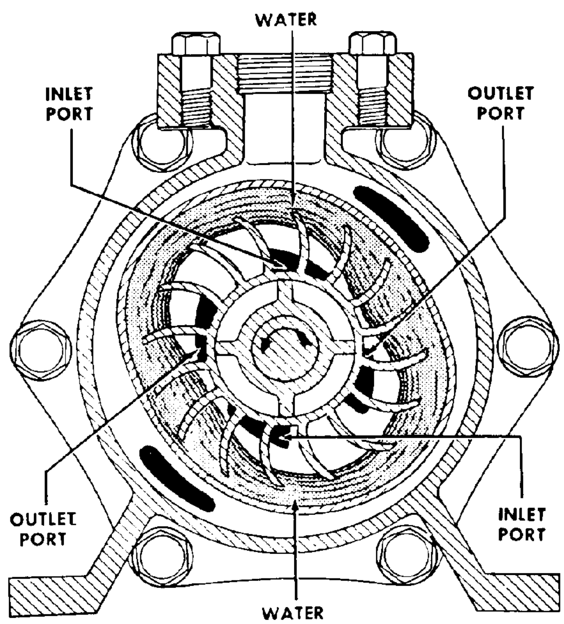


Figure 4-7. Positive displacement type vacuum pump.

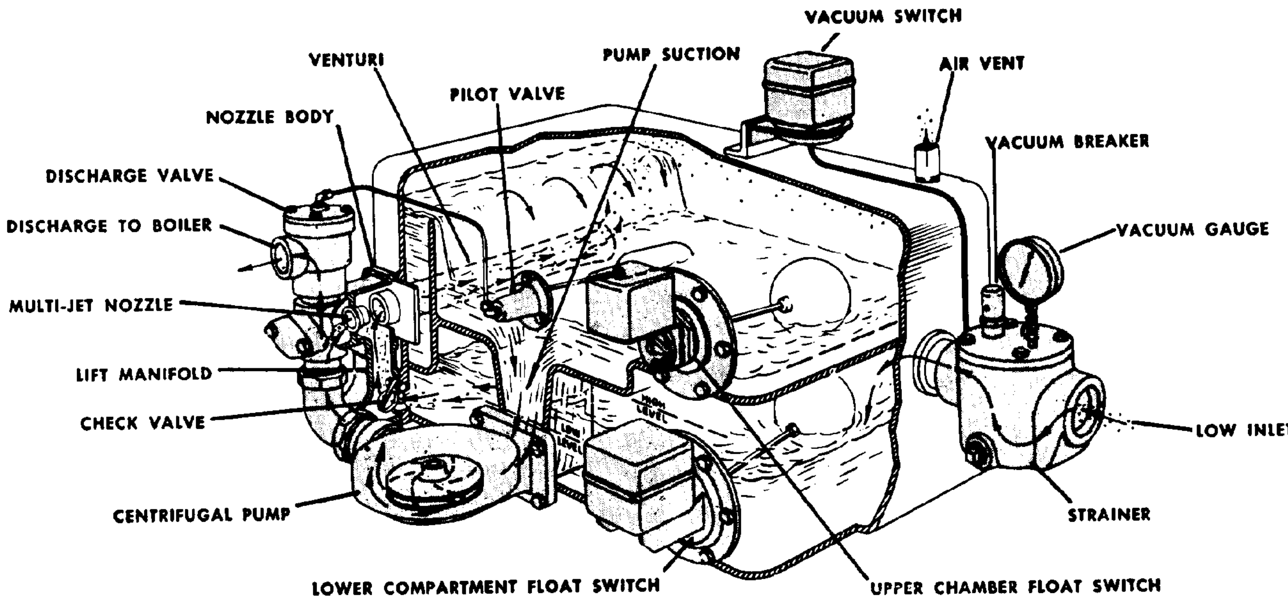


Figure 4-8. Centrifugal type vacuum pump.

a. Controls. Controls for vacuum type heating systems include boiler pressure control, vacuum and float control for the pump, and may include appropriate types of thermostatic or pressure controlled shut-off or modulating valves for control of heating elements.

b. Typical operating problems.

(1) *Radiator heat failure.* This is due to defective or clogged thermostatic traps or improper radiator pitch.

(2) *System failure.* This occurs when the vacuum pump fails to clear the system of air. The system may also fail because mains are improperly pitched or trap failures allow excessive steam leakage or water logging of steam mains.

(3) *Overflow from pump vent.* This occurs be cause of inadequate pump capacity; defective valves, jets, or pump clearances; or stoppage in the pump discharge connection to the boiler.

Section II. BOILER TYPES

4-7. Cast iron boilers.

In general, cast iron boilers are shipped in sections and assembled at the installation site. Small boilers, however, are factory assembled and shipped as a unit. Cast iron boilers are usually referred to as sectional boilers. Figure 4-9 shows a sectional cast iron steam boiler commonly used in steam heating systems. The unit shown is an independent header type, in which each section is actually an individual boiler connected to supply and return headers. The supply steam header is at the top center of the boiler; the return headers are located laterally near the foundation. Heated water rises through the vertical sections from the return water headers, and steam is taken from the supply steam header at the top of the unit. Cast iron boilers usually range in capacity from two boiler horsepower (1 boiler horsepower equals 33,500 BTU/hr) up to 100 boiler horsepower.

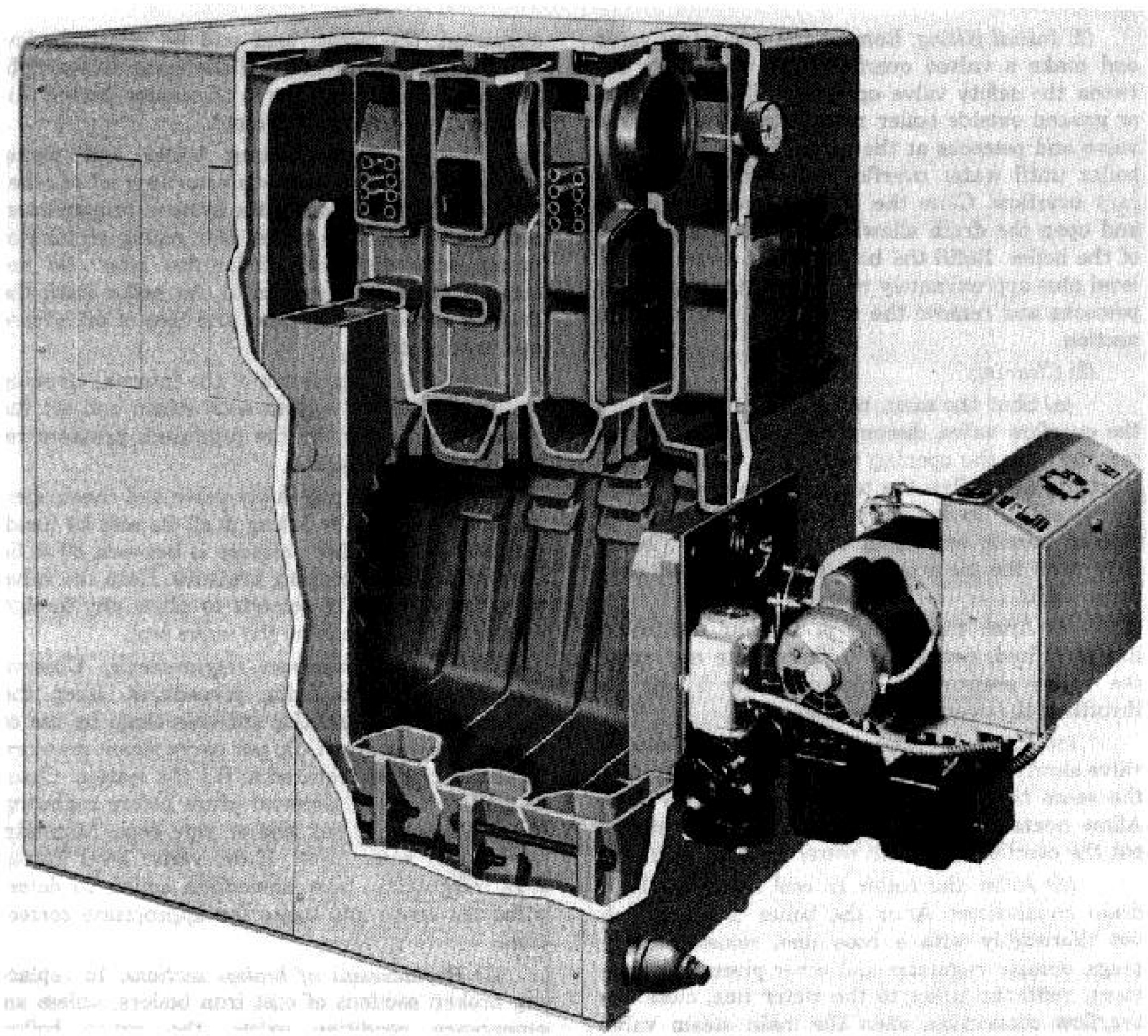


Figure 4-9. Sectional cast iron steam boiler.

a. Initial operation and cleaning

(1) *Checking.* Prior to start up after a prolonged shutdown, the complete installation should be carefully checked. Follow the steps described below:

(a) Examine the combustion chamber and gas passes; determine that all debris has been removed, and check burners or grates, if applicable, for proper operation.

(b) Check steam and return header-valves, gauge glass valves, and stop cocks for proper action.

(c) Check the damper regulator and connections (coal fired systems) and check draft dampers for proper action.

(d) Check for air leaks, particularly at the joint between sections and the base and between the base and foundation.

(e) Be sure that the make-up water and supply water piping is in good operating condition, condensate return equipment is properly connected, and that electrical connections are complete and properly fused.

(f) Determine the correct normal and low water levels. If the levels are not marked, place permanent markings at suitable locations on the front of the boiler adjacent to the gauge glass or on the frame work of the gauge glass. Manufacturer's literature should be used to determine the proper water level.

(2) *Initial filling.* Remove the pop-safety valve and make a valved overflow pipe connection between the safety valve opening and a floor drain or ground outside boiler room. Open the overflow valve and petcocks at the water line, then fill the boiler until water overflows through the temporary overflow. Close the water connections valve and open the drain allowing all water to run out of the boiler. Refill the boiler to the correct water level plus approximately two inches, then close the petcocks and remove the temporary overflow connection.

(3) *Cleaning.*

(a) Shut the main header steam valve, open the overflow valve, disconnect the damper regulator and plug the opening (coal fired systems), and start the fire. Allow the temperature of the water to rise slowly to dry out the setting and covering and to permit expansion to occur slowly, being sure that the tie rod nuts are maintained only finger tight.

(b) After the setting is dry and expansion has stabilized, increase the firing rate and raise the boiler pressure to approximately 5 psig by throttling the overflow drain valve.

(c) Partially open the cold water supply valve slowly, allowing the waterline to rise, and at the same time gradually open the overflow line. Allow heated water from the boiler to go slowly out the overflow line until water appears clean.

(d) Allow the boiler to cool and open both drain connections. After the boiler is cool, flush out thoroughly with a hose line, reinstall drain plugs, damper regulator and other pieces of equipment, refill the boiler to the water line, close the overflow connection, open the main steam valve and start a slow fire.

(e) Close radiator valves. Build up steam pressure gradually, sufficient to fill the piping system, and discharge all condensate to the sewer.

(f) Close the return connection to the pipe or boiler and open the bypass drain valve or disconnect the union in the return system. Feed the boiler with fresh water by careful manual operation. Continue this operation until the condensate appears clear, then cut in approximately one-fourth of the radiators. Continue steam generation until the condensate again appears clear; close the opened radiator valves and cut in another one-fourth of radiators, closing radiator valves after the condensate appears clear. Repeat until all radiators have been opened and cleaned out step by step. During this procedure, watch the water line closely and maintain it manually. If cut-in of mains and radiators is accomplished in steps as suggested, the boiler load will be relatively low and manual maintenance of the water line simplified. Open the drain caps in the mains during this clean-out process, if convenient.

(g) A steam heating boiler and piping system will not operate satisfactorily if oil or other impurities are present in the system. Proper internal clean-out of the boiler and piping eliminates unnecessary operating difficulties later. Do not connect the return system to the boiler until the drained condensate is clear and free of oil, grease and solid matter.

(h) After completion of the internal cleaning procedure, fill the system with steam and set the pressure regulator for the minimum pressure required to fill the system.

(i) Reinstall pop-safety valve and check operation of the valve by lifting it off its seat by hand, but only when boiler pressure is between 80 to 85 percent of preset popping pressure. Keep the valve open for at least 10 seconds to allow any foreign matter to be blown from the valve seat.

b. Special maintenance requirements. Observe and practice good firing procedures. Keep the boiler breeching and flue surfaces clean by use of a suitable wire brush. Do not carry steam pressure in excess of that required to fill the system. Clean and oil threads of cleanout plugs before replacing them. Do not use red lead or pipe dope. Maintain the correct water level. If the water level fluctuates irregularly, take immediate action to determine the cause and make the appropriate correction.

(1) *Replacement of broken sections.* In replacing broken sections of cast iron boilers, unless an emergency condition exists, the entire boiler should be dismantled and sections cleaned, inspected and reset, using new nipples. Removal of sections usually disturbs adjoining sections and considerable difficulty may be encountered in attempting to reset only a portion of the sections instead of completely dismantling and reconstructing. Manufacturers' drawings should be consulted to determine the correct arrangement of boiler sections and proper sequence for installation of boiler sections.

(2) *Replacement of defective nipples.* Before installing new nipples, nipple ports should be cleaned with solvent and lubricated with good lubricating oil. Drive nipples squarely into sections, using a block of wood and hammer. The nipple must project outside the finished face of a boiler section $^{1}/_{16}$ inch more than half the nipple's length. Use this rule to be certain that nipples project equally all around.

c. Lay-up of cast iron boilers. When the boiler is to be shut down for the summer months, remove and clean the smokepipe and reinstall it in the fall. Make all joints tight with boiler putty or cement. Clean all flues and remove soot and ashes from boiler and from the base of the chimney. Oil all door hinge bearings, damper bearings, and regulator parts. Leave doors partially open all summer to avoid condensation of moisture and rusting of interior surfaces. For water boilers, keep the system filled with water. For steam boilers, fill the boiler with water to the top of the water column. If the boiler is not to be used during the winter, draw off all of the water in the entire system. If water is permitted to freeze in boilers or radiators, breakage may result.

4-8. Steel boilers.

Steel boilers for steam heating systems may be of the fire-tube type, in which combustion gases pass through the tubes while water surrounds them; or may be of the watertube type, in which water passes through the tubes and gases circulate around them.

4-9. Fire-tube boilers.

Fire-tube boilers are almost universally used for low pressure, low capacity purposes, when it is desirable to move the boiler from place to place, or when simplicity of installation is desired. The various types of fire-tube boilers are the horizontal return tubular (HRT), scotch, firebox, and locomotive types.

a. Firebox and locomotive boilers. The firebox boiler (figure 4-10) and the locomotive type boiler are similar in most respects. However, the firebox boiler is usually used for stationary purposes only, and it has no steam dome. Firebox boilers require no setting except possibly an ash pit; as a result, they can be quickly installed and placed in service. In both types, the boiler shell extends beyond the rear tube sheet to form a smoke box or a reversing chamber. In the straight locomotive type boiler the stack is connected to this extension, while in the firebox boiler this chamber serves to reverse the flow of gases through the upper section of tubes to the front of the boiler where they are discharged to the stack.

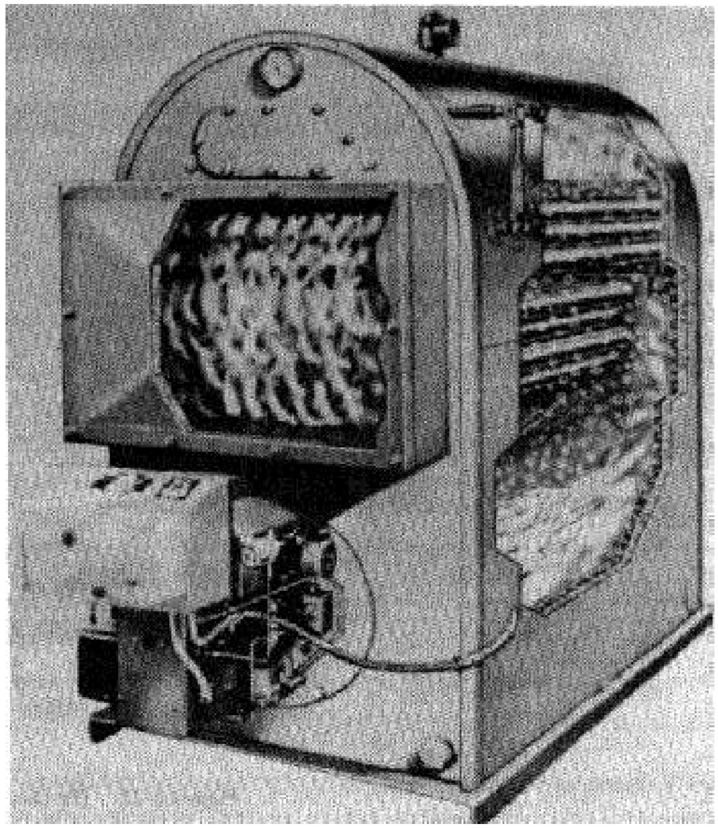


Figure 4-10. Firebox boiler.

b. Horizontal return tubular (HRT) boilers. The HRT boiler is not usually used for domestic heating installations, but is found in small plants because of its relative compactness, simple construction, and fuel efficiency. A major disadvantage is that it is difficult to keep the tubes and shell free from scale. Figure 4-11 shows a typical HRT boiler in a standard setting.

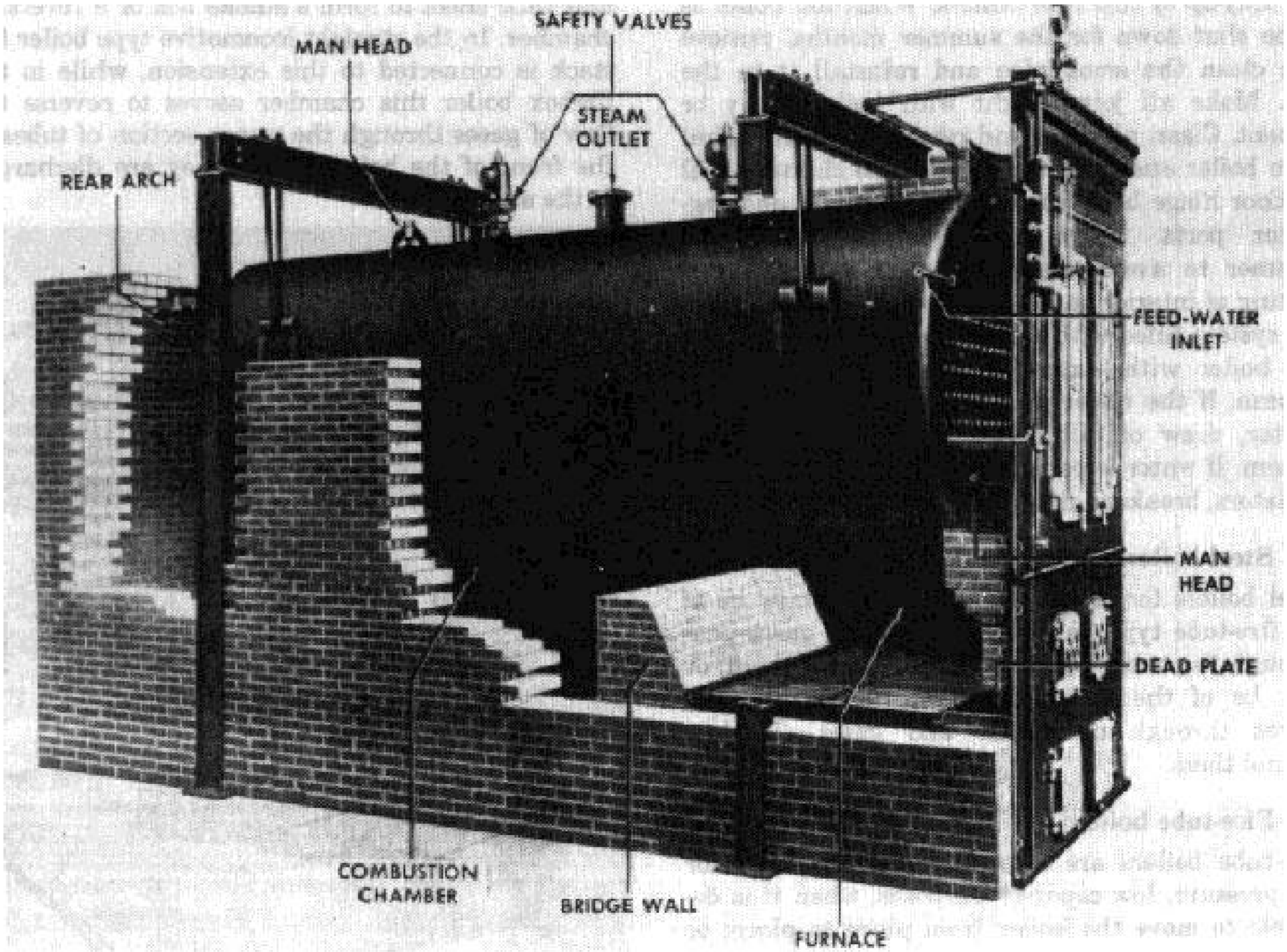


Figure 4-11. Horizontal return tubular boiler.

c. Scotch boilers. This type boiler (figure 4-12) is an internally fired unit, with a cylindrical furnace or firebox completely surrounded by water. The furnace is usually corrugated to add strength and allow for longitudinal expansion and contraction. When it is operated, combustion gases pass through the furnace into a smoke box at the back of the boiler and then return through the boiler tubes to the uptake chamber at the front.

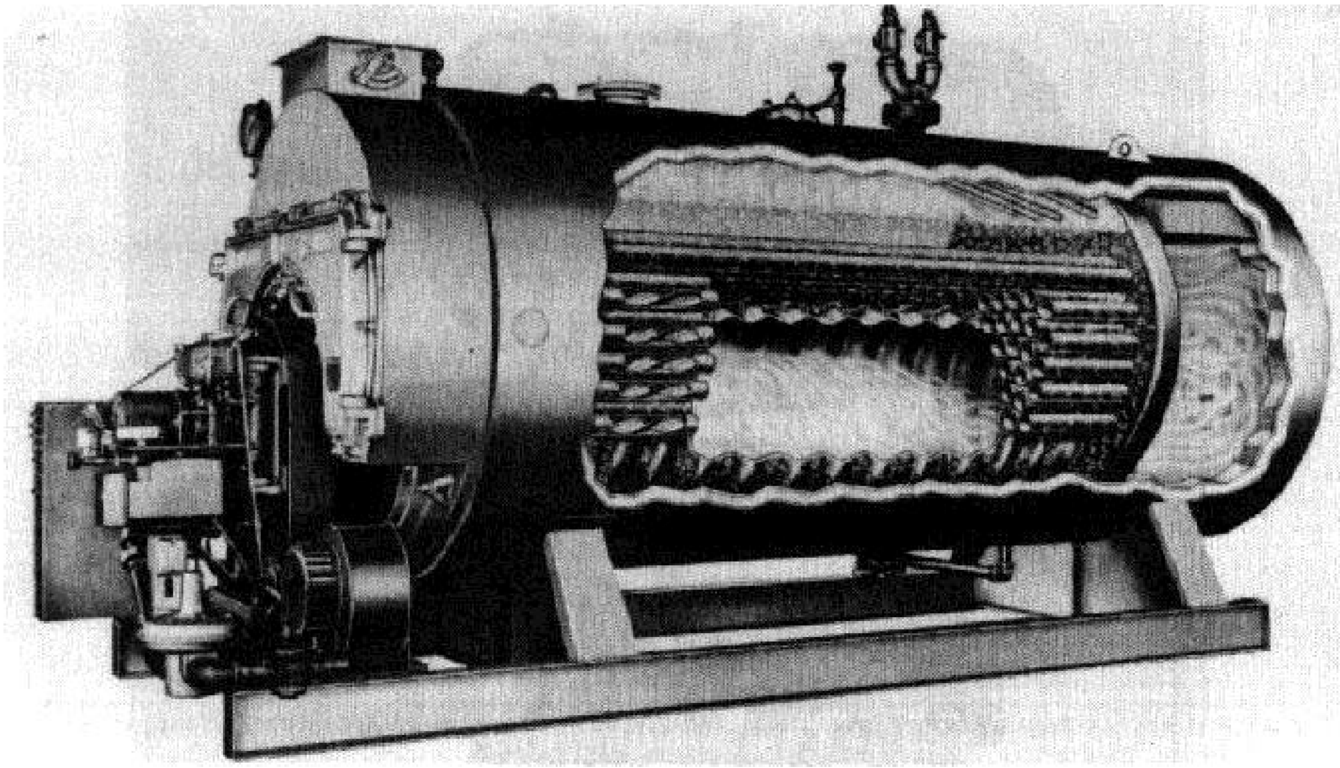
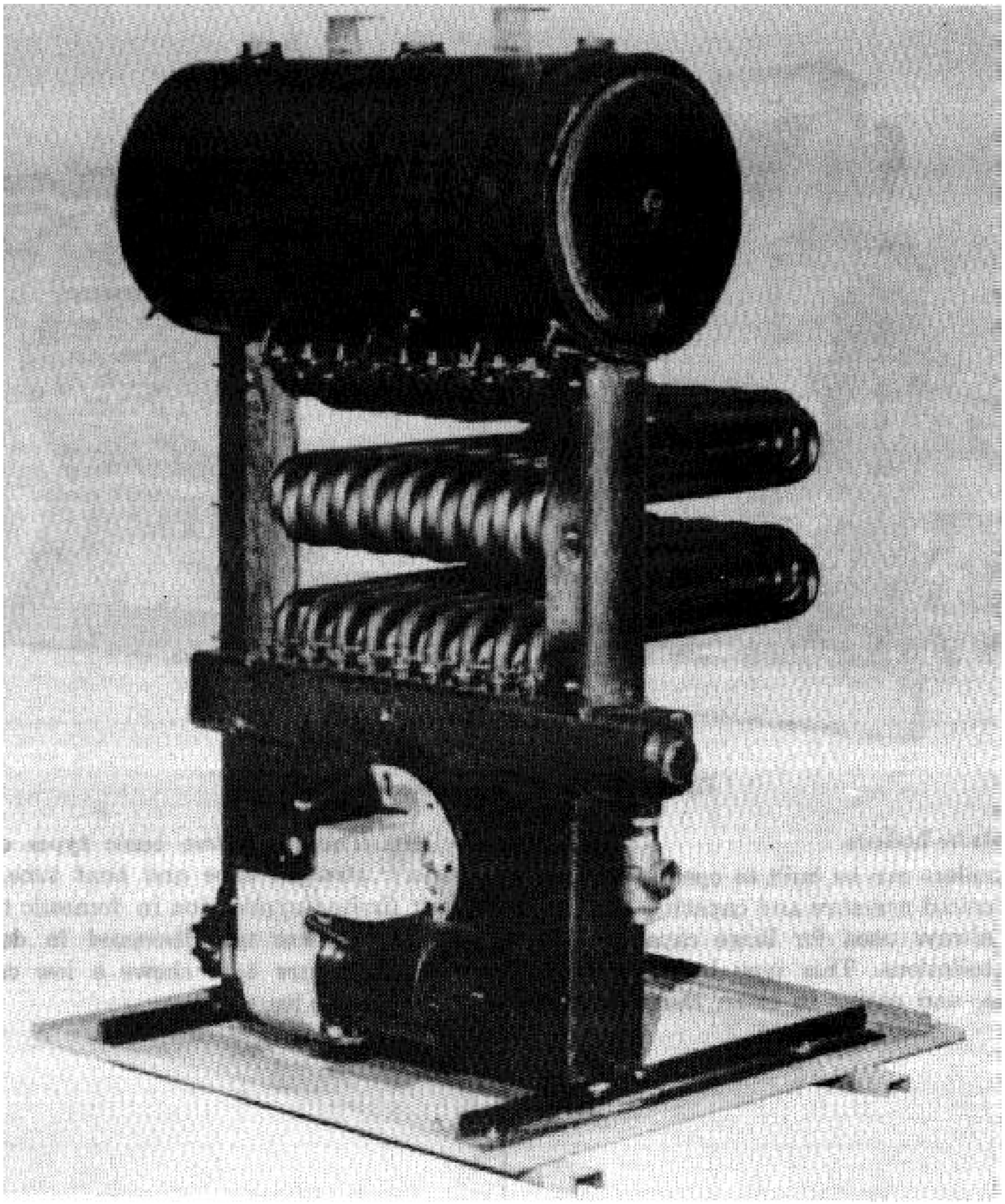


Figure 4-12. Scotch type package unit boiler.

4-10. Water-tube boilers.

Water-tube boilers can be built to operate at practically any desired pressure and capacity, but they are almost always used for large capacity high pressure installations. This type boiler is safer, more flexible, and easier to clean than fire-tube boilers. There are two basic types of watertube boilers: straight tube and bent tube. Because of their limited application in domestic type installations, they are not discussed in detail in this manual. Figure 4-13 shows a low capacity bent watertube boiler.



Fgiure 4-13. Bent water-tube boiler.

4-11. Initial operation and cleaning.

The procedure for the initial filling, cleaning of the boiler and system, and drying out of the setting is exactly the same as that for cast iron boilers, previously described. Often, considerable water will be noted at beading of the tube ends and tube sheets of steel boilers when first filled. This should not be considered cause for alarm, as this is frequently moisture from the air which condenses on the cold steel surfaces. Observe this condition closely during the initial dry out and firing operation, after which time any condensed vapor will evaporate and any leakage will usually stop. The tubes should remain tight during all subsequent usage. If slight leakage continues, beading should be gone over with a suitable beading tool.

4-12. Special maintenance requirements.

Maintenance practice for steel boilers is similar to that described for cast iron boilers. Keep the inside and outside surfaces of boilers clean and free of scale, slag, and soot. Keep combustion chambers and burners or grates clean. Remove ash from ash pits of coal fired boilers and, if applicable, remove clinkers from stokers immediately. Carry the steam pressure at minimum necessary to fill the system. Operate with a constant correct waterline. Eliminate water or steam leaks in the system and reduce make-up to a minimum.

Section III. BOILER HEADERS, VALVES AND PIPING CONNECTIONS

4-13. Installation.

Exercise care and give careful consideration to proper installation of steam and return headers for either cast iron or steel boilers. Arrange piping to permit free expansion without placing undue stress at the boiler connections. To assure proper steam delivery conditions, utilize all steam outlets of cast iron boilers. Equalize the steam supply and return headers through an interconnection in the form of a vertical line running the same pipe size as the steam supply header to the waterline, and then reducing to the return header pipe size. Connect the system return, either gravity or pumped discharge, to the vertical equalizing line, and place the bottom of the connection at the minimum safe boiler water level. This is known as a Hartford Loop. (See figure 4-14.) It eliminates unsafe lowering of boiler waterline due to back up of boiler water into the return line, which may occur due to check valve failure or excessive pressure drop in returns. Arrange pipe connections, both supply and return, to the header so that expansion and contraction in the system piping will not cause excess stress to the headers. Support pipe connections to the header with properly adjusted hangers or pipe columns to eliminate strain at boiler connections. Install a steam shut-off valve and a globe valve at the return connection to the vertical equalizing line of each boiler. Locate valves so they can be fully opened and closed without interference from building construction or other piping. Arrange the return header connection so it is readily accessible for cleaning, draining, and rod-ding, and provide it with a plugged opening. Use plugged tees instead of elbows at return connections to boilers to provide ample cleanout facilities. Connect the boiler feed or makeup connections into a common return or pump discharge header before the Hartford Loop. Feed or makeup water should not be discharged directly into any part of a boiler exposed to the direct heat from the fire. Feed water should not be introduced through openings or connections used for the water column, water glass, or gauge cocks.

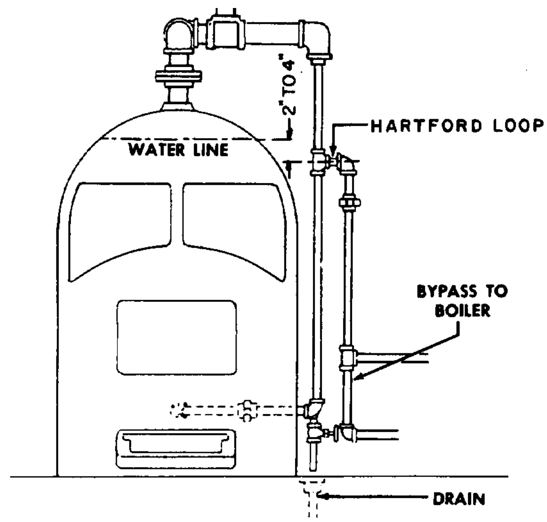


Figure 4-14. Hartford loop.

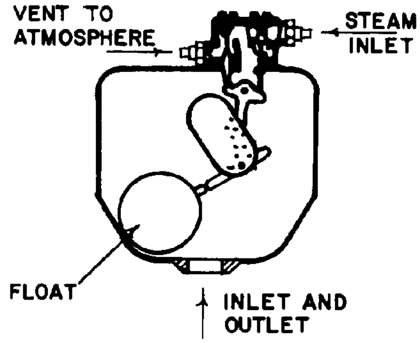
4-14. Maintenance.

Maintain joints, fittings, and flanges free of leaks. Maintain proper packing in valves and do not allow the main steam valve to remain in a cracked or partially open position. This valve should be either tightly closed or fully opened to avoid corrosion and wearing of the stem, seat, and disk. Close and open this valve periodically during the heating season to check for tightness and proper operation. Open drain caps and connections periodically to flush out the return header and to assure free flow of return condensate.

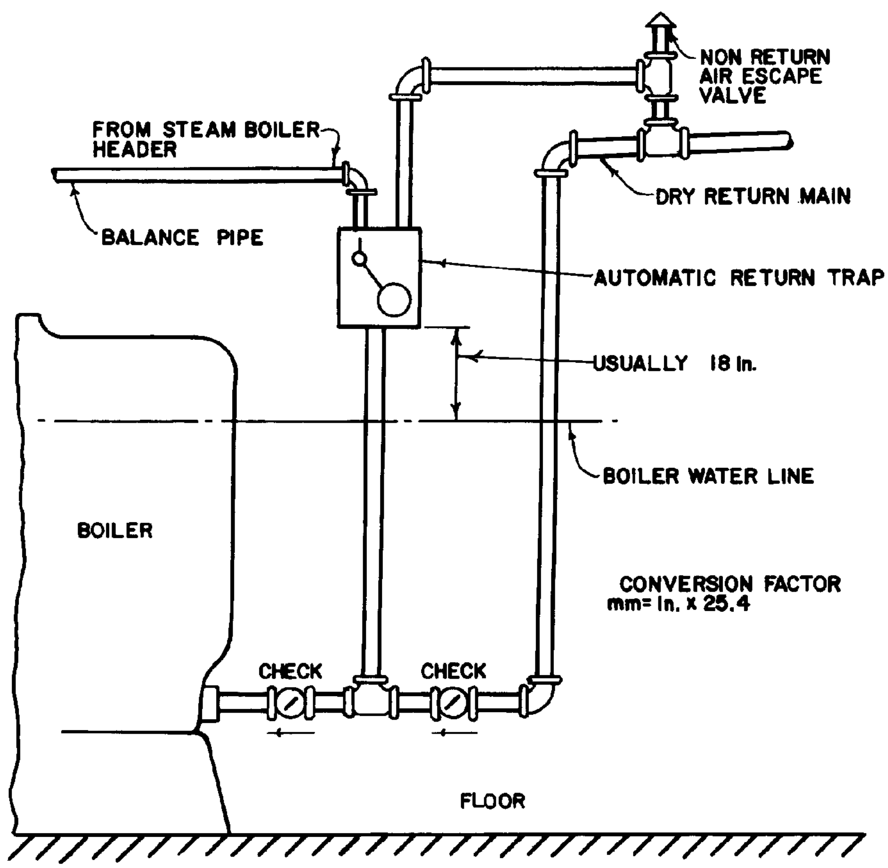
Section IV. BOILER RETURN TRAPS

4-15. Installations.

All boiler return traps are similar in basic principle or construction. (See figure 4-15.) They include a float element which may either directly, or indirectly through a level linkage, actuate a steam inlet or boiler equalizing valve and a vent valve. Because the valve linkage requires close adjustment, it is necessary that the return trap be installed perfectly level and so suspended that this level will be maintained. The top of the return trap must usually be no higher than the bottom of the dry return main and the bottom of the return trap should not be less than 6 inches above the waterline of the boiler. Piping connections should be arranged so that expansion and contraction does not throw the trap out of level. The steam or boiler pressure equalizing valve consists of a valved connection to the main steam supply header if two or more boilers are used, or a connection ahead of the boiler steam valve in single boiler installations, and has unions immediately ahead of the return trap connection to enable access to the valve mechanism. A vent or return equalizing valve is connected directly to the venting unit. Two check valves are installed at the base of a valved riser to the bottom of the return trap, one on the return side and one on the supply side. The check valves should be angle type and arranged so that flow is in the direction of the boiler. Air eliminator or vent traps are installed similar to return traps, including leveling of vent. The vent trap is installed so that the inlet from the dry return is in a straight line with the inlet to the vent trap.



BOILER RETURN TRAP OR ALTERNATING RECEIVER



TYPICAL CONNECTIONS FOR AUTOMATIC RETURN TRAP

Figure 4-15. Boiler return traps.

4-16. Initial operation.

Keep connections to the return trap and vent traps closed during the boiler cleaning process. After completion of all connections to the vapor heating system and cleaning of the system, open the valves to the return trap. The grease and dirt from the system should not enter the return and vent trap during the system clean out process. To avoid this, condensate should be discharged to the sewer. After clean-out, raise steam pressure to the pressure equivalent of the static head between the dry return main and the waterline of the boiler. Continue to raise pressure slowly, observing the boiler waterline closely. By means of a stethoscope or a metal rod placed against the trap casing, check the return traps for tripping. The intervals between trip depends on the rate of condensate return from the system and the storage capacity of the return trap. During the pressure raising period, the sound of air leaving the vent valve of the air eliminator will be easily heard. Air vent valves or air check valves should be cleaned periodically with a dry cloth. Remove the air valve or check cap and lift out the disc or ball which is designed to permit ready and quick access for careful clean-up of the seat and check. Clean return trap steam valve and air relief valves periodically to ensure reasonably tight seating. To clean these valves, disconnect the steam and vent connections and lift out the valve assembly or caps by means of hex head fittings provided for this purpose. Do not use emery cloth, abrasives, or files in cleaning valve seats or discs.

4-17. Maintenance.

Check and clean trap interior. Check for excessive wear of leverage pins and bearings and check float to assure that no leaks are present. Remove rust, scale, and grease accumulations thoroughly from moving parts by means of a soft cloth free of grit.

4-18. Typical operating difficulties.

In return traps, the usual difficulty is failure to return condensate to the boiler and is caused either by air binding due to failure of the air eliminator, or failure of the valve tripping mechanism because of worn parts, trap out of level, or leverage and weights out of adjustment. Defective traps should be repaired, returned to the manufacturer for adjustment, or replaced.

Section V. CONDENSATE PUMPS

4-19. General.

Pumps are generally well designed, skillfully built and rugged, but must be given the same careful attention that is necessary for any precision machine. Figure 4-16 shows a centrifugal pump and receiver set.

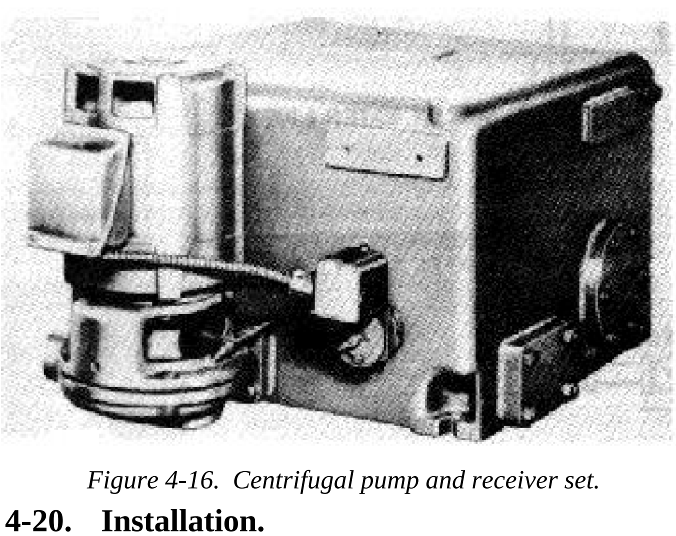


Figure 4-16. Centrifugal pump and receiver set.

4-20. Installation.

Pumps should be installed with short, direct pipe connections, and located so that equipment will be accessible for inspection and care. The unit should be placed so condensate flows by gravity into the receiver. The top of the receiver must be below the lowest return to keep return lines dry. If the unit must be set in a pit, adequate drainage should be provided.

a. Foundation. For performance and quiet operation, the condensate pump unit is bolted to a substantial foundation. The anchorage system has anchor bolts shouldered on loose fitting vertical sleeves of pipe which are imbedded in a concrete foundation. This arrangement permits bolt adjustment to conform accurately with subbase holes after concrete is poured.

b. Alignment. Condensate pumps are aligned at the factory, but alignment may become disturbed. Although the unit is equipped with a flexible coupling connection which compensates for slight variations, it is desirable to obtain exact alignment as far as possible. Check the alignment by placing a straight edge across coupling halves with a thickness gauge or outside caliper at two or more points 90 degrees apart. Shim the pump or motor, or shift the motor until correct alignment is attained. Leave at least a $^{1}/_{6}$ inch metal to metal clearance between coupling pins and faces. Adjust coupling halves on shafts so that the buffer fits loosely. Check alignment and clearances both before and after pipe connections are made.

c. Piping. In connecting pipes to a pump or receiver, a union is included in each line as close as possible to the unit for ease in installation or repair. Extreme care should be exercised to prevent any pipe strains upon the unit. Pipes used should not be smaller in size than their connections on the unit and should be at least one or two sizes larger if runs are long.

(1) *Condensate return line.* The condensate return line is pitched downward so that the return line remains “dry”. A valved mud leg or bleeder branch is installed to permit the return system to be flushed. A gate valve is included in the line between the mud leg and receiver.

(2) *Boiler return line.* A tight seating check valve and a gate valve are included in this line. The check valve is nearer the receiver, and a plugged opening is provided for insertion of a pressure gauge for pump testing. The line is connected to the boiler by the Hartford Loop.

(3) *Vent.* For systems where boiler pressure is to remain below 15 psi, a mounted vent assembly is furnished on the receiver which includes a pet-cock and swing check valve. This requires no alterations or additions except, perhaps, to raise the assembly to a drained level when the pump is installed in a pit. Discharge from vents must be so located that they do not endanger personnel.

(4) *By-pass.* If returns and heating units are above the boiler water line, a valved bypass is provided between the receiver inlet connection and the pump discharge connection. If the heating units and returns are not above the boiler waterline, valved drains are provided.

d. Controls. For protection and convenience, a fused switch is always provided in the motor circuit to disconnect the motor. A standard condensate unit is usually provided with a receiver mounted float control switch which closes and opens the motor circuit at high and low water levels in the receiver tank. This switch can only control motors listed on the switch nameplate according to horsepower and current characteristics. All larger motors require, in addition, a suitable starter which affords protection against high inrush current, low voltage, high voltage, overloading, or phase failure. All polyphase motors, regardless of size, must have a starter for protection. When a starter is used, the float switch functions as a pilot.

e. Wiring. Electrical power connections must be made according to wiring instructions accompanying switches and motor. Conduit and wire sizes must be as required by national and local codes. The characteristics of voltage and frequency indicated on the motor nameplate must be the same as those of the electrical service provided.

f. Rotation. Check rotation of the motor. The pump must turn in the direction indicated by the rotation arrow on the pump casing. If the rotation is incorrect, see the motor manufacturer’s instructions for the procedure to be used in reversing direction.

g. Fuses and thermal units. Fuses should be installed which comply in size with local codes. Note fuse size advised on yellow fuse caution card, when furnished, or recommended in motor manufacturer’s instructions. In general, if no motor protective devices such as magnetic starters or thermal relays are used, a fuse rated at 125 percent of motor nameplate full-load current is acceptable. If motor protective devices are installed, a fuse rated at 150 percent of nameplate current should be used. If a thermal cutout is used, see switch instructions for choice of fuse rating. In general, an element is selected with an ultimate tripping current rating not over 125 percent of motor nameplate full-load current. Fuses rated higher than those recommended should never be used.

4-21. Operation.

Before putting a replacement pump into service, the heating system should be operated for several days with the condensate return line open to a drain until water appears clear. This thoroughly flushes and cleans the system to prevent clogging or damage to the new pump when condensate is allowed to enter the receiver. The procedure may take from 4 days to 2 weeks during which time the boiler water level must be maintained by addition of clean water. All pits and other floor openings should be covered or provided with guard rails.

a. Before starting.

(1) Be sure the pump and motor are lubricated according to instructions.

(2) Turn the pump shaft by hand to see that it rotates freely.

(3) See that the voltage and frequency on the motor nameplate are the same as the electrical service provided.

(4) See that switches are regulated for operation and that thermal units are set.

(5) Check motor rotation direction by closing switch contact momentarily (“bumping” the motor).

(6) Be sure valves are open on the boiler return and condensate return lines, and that the valve on the bleeder line is closed.

(7) On low pressure units, be sure the vent pet-cock is open. If it is closed, the receiver will not fill properly.

(8) Close the motor disconnect switch. The pump will not operate unless the receiver is full enough to close the float switch.

(9) Be sure all guards are in place before starting the unit.

b. After starting.

(1) On low pressure units, adjust the vent pet-cock so that it is open just sufficiently to allow escape of steam and air as rapidly as condensate flows into the receiver.

(2) See that motor rotates in proper direction.

(3) See that all pipe connections are tight.

(4) See that the float switch starts and stops the pump at desired levels of water in the receiver.

(5) See that the motor picks up speed quickly and maintains a constant rotation rate. If motor is brush type, see that it does not spark profusely.

(6) Check the packing-gland adjustment.

(7) Observe operation of the unit closely for 3 hours after starting and at regular intervals thereafter. A new, properly operating pumping unit should be carefully watched to note its initial performance, for later comparison checks. Consult manufacturer’s instructions.

4-22. Maintenance.

a. General.

(1) At regular intervals lubricate the pump and motor as specified in lubrication instructions.

(2) Maintain proper adjustment of the packing glands and change packing when deteriorated.

(3) Keep the inside and outside of the motor and controls free of moisture, oil and dirt. If necessary blow out their interiors with a bellows. If switch contacts become corroded or pitted they should be smooth and treated with a contact preserver or replaced. If the motor is of the brush type, replace the brushes when necessary.

(4) Wearing parts on centrifugal pumps, such as bearings and wearing rings, are readily accessible. To get peak performance, check these parts at intervals depending upon severity of service, and replace worn parts if necessary.

(5) To ensure the best operation of the unit make a systematic inspection periodically.

b. Packing boxes.

(1) *Gland adjustment.* Adjust packing glands so there is a weep or slight leakage of water around the shaft when the pump is operating. This is necessary for cooling and lubrication, and keeps the packing in good condition. To adjust glands, tighten or loosen the two gland nuts evenly a few turns. Do not make glands too tight. After adjustment, turn the shaft by hand to be sure it rotates freely. If proper adjustment cannot be attained without shaft binding, the packing should be replaced. Provide proper drains from pump bases.

(2) *Packing replacement.* Occasionally packing will require replacement because of normal wear or improper gland adjustment which causes drying or burning. Use only soft, square, packing of proper size. Cut packing into rings which will fit snugly around shaft with ends just meeting. Be sure the ends are square. Remove gland nuts, take out gland halves and pick out old rings of packing. Clean the shaft and packing box of dirt or sediment and insert packing rings, pushing each succeeding ring back into place. Stagger packing ring joint ends to ensure a good seal. Reinstall gland halves, bolts, and nuts, and be sure that gland followers enter the packing box to a depth of at least **‘/8** inch. Adjust the glands.

c. Shutting down. When shutting the pump unit down for any considerable period, open the motor disconnect switch. Drain the unit by removing drain plugs at the bottom of the receiver tank and pump casing until all water drains out. Never expose the pump unit to freezing temperatures when filled with water. Cover the motor and switches to protect them against dust and moisture.

d. Pump lubrication. Keep a regular lubrication schedule and avoid both over and under lubrication. When oil lubrication is used, a good grade neutral, medium viscosity, mineral oil is satisfactory. Grease lubrication requires more careful lubricant selection, because there are a great many products from which to choose. The important factors in choice of grease for a pump are: its resistance to water, determined by the soap-base used in its manufacture; and its consistency as related to operating temperature and method of application. Lime-soap-base greases are relatively insoluble and non-emulsifying and should be used where water may come in contact with the bearing. The higher the operating temperature, the heavier the grease should be. Use only ball bearing lubricants for grease lubricated ball bearings; never use graphite. Lubricate the motor according to directions on the motor instruction sheet.

4-23. Typical operating difficulties.

a. Pump fails to operate.

(1) Fuse blown or thermal unit is tripped or loose.

(2) Shaft binding, or impeller blocked.

(3) Switch contacts corroded or shorted, or terminal connections broken somewhere in circuit.

(4) Float control mechanism not functioning or float waterlogged.

(5) Wiring hookup or electrical service provided is incorrect, or switches are not set for operation.

(6) Motor is grounded or burnt, or brushes, when present, are stuck or worn.

(7) Electrical service or phase failure.

(8) Receiver vent is not open.

b. Fuses blown or thermal units trip.

(1) Fuse rating used is incorrect.

(2) Shaft is stuck or not rotating freely.

(3) Loose connection somewhere in circuit.

(4) Controls are worn or arcing.

(5) Motor is grounded or partially burnt out.

(6) Brushes, when present, are sparking profusely or sticking. Commutator is scored or brushes worn.

(7) Motor is overloading.

(8) Fuse or thermal unit location is too hot if placed near boiler or flue.

(9) Short circuit in wiring.

c. Pump runs continuously.

(1) Float is stuck in raised position.

(2) Float switch adjustment is improper.

(3) Switch contacts are burnt closed.

(4) Pump is “steam bound” due to very high water temperature.

(5) Discharge head is higher than anticipated.

(6) Motor speed is too slow or voltage low.

(7) Pump is defective or capacity too small.

(8) Receiver is dirty. Pump suction clogged.

(9) Vacuum in receiver is reducing discharge head on pump. See that vent is open.

d. Pump operates at slow or variable speed.

(1) Switch contacts are arcing.

(2) Loose connection in electric circuit.

(3) Low voltage, or phase failure in polyphase electrical service.

(4) Motor is partially burnt or grounded.

(5) Motor brushes, when present, are worn, stuck, or spring tension is weak. Commutator may be corroded.

(6) Clutch is defective in single phase repulsion induction motor.

(7) If shaft is binding, check for improper gland adjustment, impeller rubbing, impeller clogged, or a bent shaft.

4-24. Steam pressure pumping systems.

a. General. This type of condensate handling system is an energy saving, highly efficient way to pump or lift liquids in many types of operations. It is particularly suited for effectively handling condensate from all types of heating and processing equipment. Instead of using motor driven pumps, this system uses steam or other gases under pressure as the motive force. Unlike conventional condensate pumps, a steam powered pump can handle temperatures over 185 °F without the need for venting or cooling. It requires no high maintenace stuffing boxes, motors or starters. It contains no revolving shafts and utilizes a minimum of moving parts.

b. Operation. Figure 4-17 shows the operating cycle for one type of steam powered pumping system. Condensate from the equipment being drained enters the receiver tank and flows down the fill line into the equalizing chamber (figure 4-17(1)). When a predetermined high level is reached in the equalization chamber, the level control system sends out a signal which causes the 3-way valve to cycle. When this valve cycles, the vent line is closed off and high pressure steam is admitted to the equalization chamber. This steam pressure is confined above the condensate in the chamber and its effect is to move the condensate out of the chamber and into the discharge line. When the condensate reaches a predetermined low level, the level control system sends another signal causing the 3-way valve to revert to its original position. Residual steam remaining in the equalizing chamber will flow through the vent line into the receiver enabling the pressures in the two tanks to equalize with each other. When this is completed, flow of condensate from the receiver tank to the equalizing chamber will start again. The cycle then repeats itself.

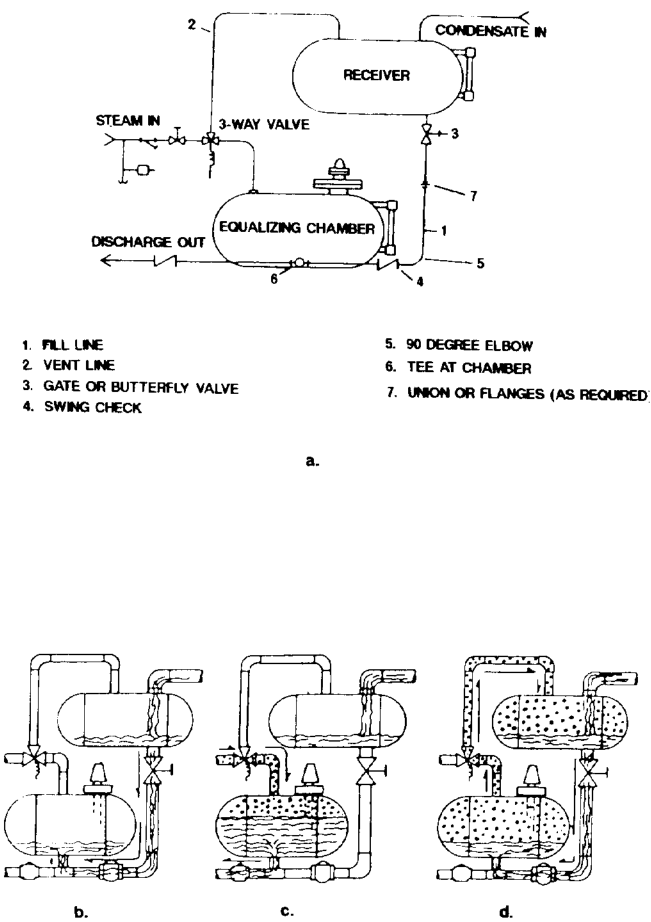


Figure 4-17. Steam pressure pumping.

(1) *Fill cycle.* When condensate from equipment being drained enters the receiver, it will also enter the fill line connecting the two tanks (figure 4-17(2)). Since the 3-way valve is not energized, its normally open port will allow both tanks to be pressure equalized through the vent connection. Therefore, the flow of condensate is by gravity head only. Typically, gravity head is 1 to 3 psi. Therefore, it is important that friction losses be minimized. While filling is taking place there is no steam flow through the 3-way valve and no condensate flow into the discharge line. The check valve in the discharge line prevents back flow into the equalizing chamber. The fill cycle is complete once the condensate reaches the predetermined high level of the equalizing chamber. At this moment the level control device sends a signal causing the 3-way valve to actuate. This signal can be electrical or pneumatic. When the 3-way valve actuates, it closes its normally open port in the vent line and opens its normally closed port in the steam line.

(2) *Equalization and discharge cycle.* The steam flow through the 3-way valve enters the equalizing chamber at a point above the condensate (figure 4-17(3)). The initial pressure in the tank immediately begins to increase. Until tank pressure exceeds discharge line pressure no condensate will be discharged. This period is called the equalization cycle and represents a small fraction of the discharge cycle. As the tank pressure increases above discharge line pressure, condensate flow starts and will continue until the predetermined low level is reached. At this time the level control device sends a signal which allows the 3-way valve to revert to its original position.

(3) *Vent cycle.* Several events take place during the vent cycle (figure 4-17(4)). In its closed position, the 3-way valve prevents high pressure steam from entering the equalizing chamber, but its normally open port will allow the steam used for discharge to flow into the receiver through the vent line. Until this steam pressure is equalized with the receiver, no condensate flow will occur between the two tanks because the residual pressure keeps the fill line swing check closed. Condensate entering the receiver during discharge and vent cycles remains in the receiver until the next fill cycle begins.

c. Troubleshooting. As with any troubleshooting procedure, care should be exercised when disassembling a pipe line, valve or other pressure fittings. Steam and condensate lines should be valved off and initial inspection should be made to ensure that no residual pressure remains in the valved off section(s). This same care should be followed when working with the electrical components. A troubleshooting guide for steam pressure powered pumping systems is in appendix C.

Section VI. VACUUM PUMPS

4-25. General.

a. The usual vacuum pump unit consists of a vacuum section which withdraws the air-vapor mixture and discharges air to the atmosphere, and a water removal unit which discharges condensate to the boiler. The vacuum pump unit is furnished complete with a receiver, separating tank, and automatic controls mounted as an integrated unit on one base. There are also special steam turbine driven units which are operated from the heating system steam supply. Under special conditions such as an installation where it is necessary to return condensate to a high pressure boiler, auxiliary water pumps are supplied. In some instances separate air and water pumps are used.

b. For rating purposes, vacuum pumps are classified as low and high vacuum. Low vacuum pumps are those rated for maintaining less than 5½ inches of mercury vacuum in the system and high vacuum pumps are those rated to maintain vacuum at or above 5½ inches.

c. It is essential in vacuum installations that the entire system is tight in order to reduce the amount of inward air leakage. Furthermore, it is essential that very high temperature steam is prevented from entering vacuum return lines through leaky traps and high pressure drips. The condensate from equipment using steam at high pressure should not be connected directly to a vacuum return line, but should drain to a receiver or flash tank through a high pressure trap. The receiver should have an equalizing connection to a low pressure steam main and drain through a low pressure trap to the vacuum return main.

4-26. Installation.

a. General. Figures 4-18 and 4-19 illustrate correct methods for installing vacuum pump units. In connecting pipes to the pump or receiver, a union is included in each line as close as possible to the unit for convenience in installation or repair. Pipe stress upon the unit should be prevented. Pipes used should not be smaller in size than their connections on the unit and should be at least one or two sizes larger if runs are long.

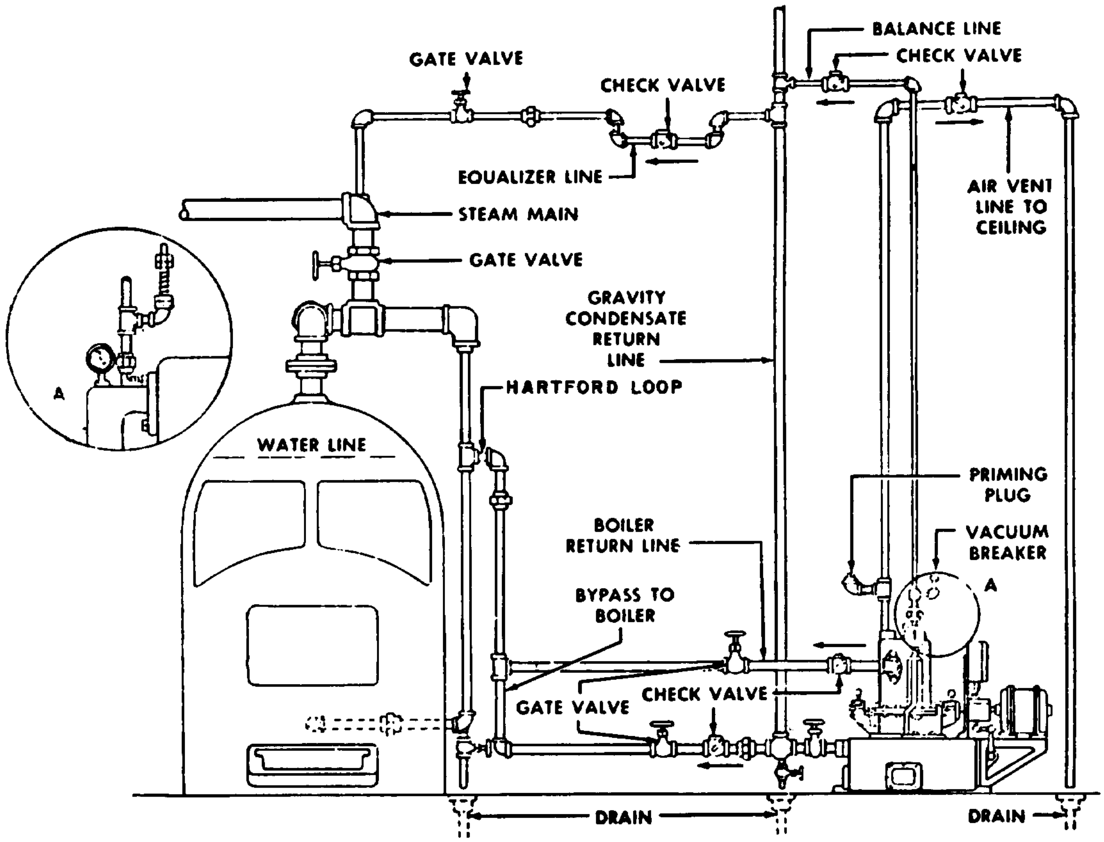


Figure 4-18. Single vacuum pump installation.

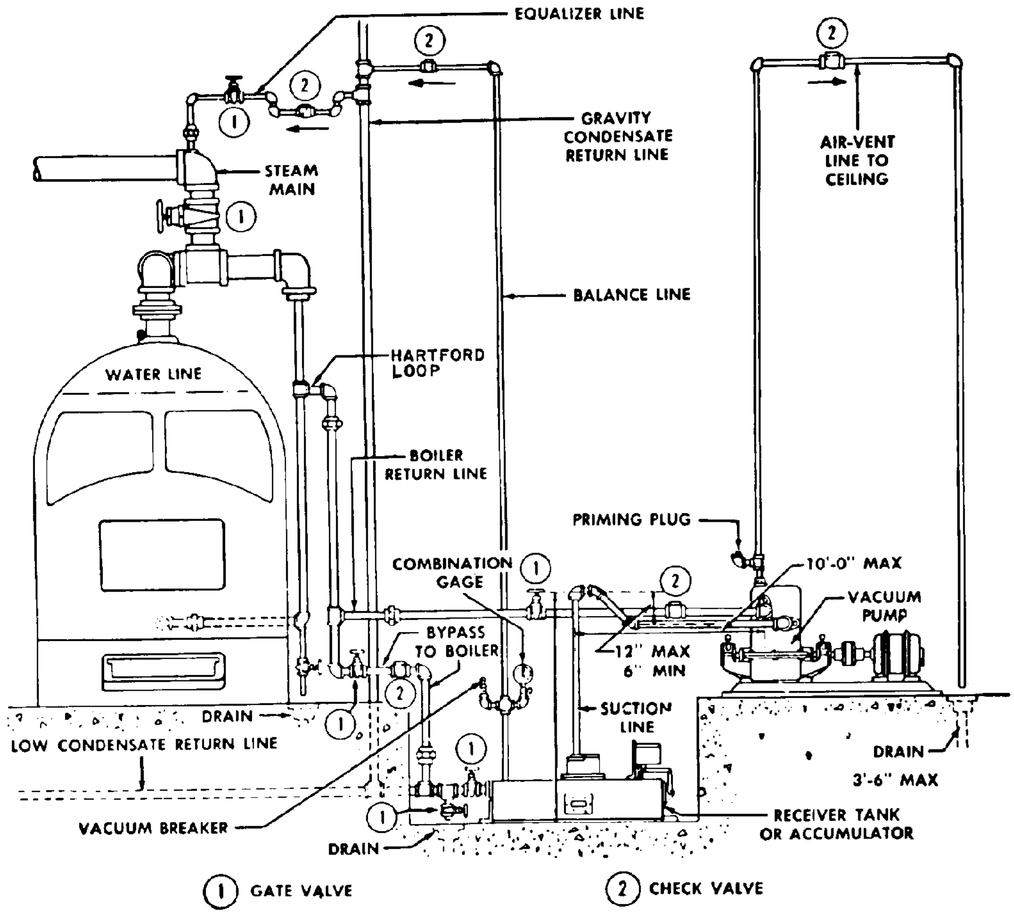


Figure 4-19. Single vacuum pump installation with accumulator tank.

b. Pipe connections.

(1) A valved connection to a drain in the condensate return line is installed to permit draining or flushing of the system.

(2) A valved bypass from the condensate return to the boiler return line is installed to permit operation by gravity in case of a power failure.

(3) The boiler return line is connected by Hartford Loop.

(4) A receiver vent or equalizer line to a dry vertical return riser is used to permit a continuous flow of condensate into the receiver.

(5) An air-discharge vent line with a horizontal switch check valve is run up to a point as close to the ceiling as possible and back down to a drain.

(6) A dry equalizer line between the condensate return line and steam header, including a gate valve and tight seating check valve, is used to equalize boiler vacuum when steam is shut off and to permit normal return of condensate to pump receiver.

(7) Pipes must be airtight and all steam traps must be of a suitable type, properly located, and in good operating condition.

4-27. Controls.

The vacuum pump is controlled by a vacuum regulator which cuts in when the vacuum drops to the lowest point desired and cuts out when the vacuum has been increased to the highest point. These points are varied to suit particular system or operating conditions. In addition to this vacuum control, a float control is included which automatically starts the pump whenever sufficient condensate accumulates in the receiver, independent of the amount of vacuum in the system. A selector switch is usually provided to allow the vacuum pump to operate as a condensate pump. This operation takes place on float control and when vacuum control is in the off position. The selector switch also provides manual or continuous operation when desired. A fused motor-disconnect switch is always provided in each motor circuit. Exclusive of continuous duty models, all standard vacuum pump units are furnished with automatic controls necessary for requirements of the motor furnished. A float switch governed by the water level in the receiver and a vacuum regulator controlled by the vacuum in the system are provided. In addition, all vacuum pump units have a three-way selector switch for choice of continuous operation, operation with float and vacuum control, or operation with float control only. This permits, among other things, cutting out the vacuum regulator when vacuum is not required.

4-28. Initial operation and cleaning.

Piping systems may contain considerable quantities of scale, grease, dirt, or metal shavings. To protect against damage from foreign material, the heating system should be operated for 2 weeks with the condensate return line open to a waste drain before the pump is first put into operation.

a. Before starting Check the following items before starting the unit.

(1) Be sure the pump and motor have been lubricated as indicated by the manufacturer's lubrication instructions.

(2) Turn the shaft by hand to see that it rotates freely.

(3) See that the characteristics of voltage and frequency on the motor nameplate coincide with the electrical service provided. Check to see that all thermal units are "set" for operation.

(4) See that the drain valve is closed and all necessary line valves open.

b. Priming the pump. Most vacuum pumps must be primed before the pump is put into operation. To do this, remove the priming plug which is on the air vent line just above the pump and pour clean water through the elbow fitting into the pump casing. Replace the plug.

c. Starting the pump. Set the selector switch for float and vacuum control, or continuous operation, and close the motor disconnect switch.

d. After starting pump. After the pump has been started check the following items.

(1) See that the shaft rotates in the direction indicated by the rotation arrow on pump. Vertical units rotate clockwise looking down the motor. Horizontal units rotate clockwise looking at the pump from the motor end.

(2) On larger units, check the flexible coupling connection of the pump and motor shafts, and note if the pump is noisy. If so recheck for improper alignment or clearance.

(3) Check pump operation and control adjustment by closing the gate valve on the condensate return line and running pump on float and vacuum control. Observe the operating time necessary to create the vacuum for which the pump is set.

(4) Open the gate valve on the condensate return and check the time required for the pump to create a vacuum in return system, keeping in mind that in large systems a reasonable period may normally be necessary.

(5) Check the packing boxes for proper leakage.

(6) After the pump is in operation, clean the inlet strainer as required by the manufacturer's instructions.

e. Vacuum regulation. Regulate the pump to create the vacuum desired by adjusting a spring tension nut in the vacuum control switch according to directions given in the switch instructions. The normal range is from 2 to 6 inches of mercury vacuum.

f. Vacuum breaker valve. The vacuum breaker or relief valve is usually set to open at 10 inches of mercury and is adjusted by regulating the tension of the valve spring. The relief valve ordinarily requires no special care. It is used to relieve excessive vacuums that might result when float control is still activated after the desired vacuum has been created.

g. Selector switch. Selector switches provided on vacuum pump units with automatic control have three positions for pump operation marked Continuous, Float and Vacuum, and Float Only. Properly handled, this feature permits a flexibility of operation yielding both economy and effective pump performance. A few recommendations for operation of the selector switch are given below:

(1) *"Continuous".* The pump will run continuously independent of float or vacuum switches. This mode of operation is used:

(a) To run the pump continuously for trial test, or under unusual service conditions.

(b) To ensure rapid heat-up in the morning.

(2) *Float and vacuum.* Pump operation is governed by either vacuum regulator or float switch. The pump operates when water is accumulated beyond a set level in the receiver tank or when vacuum in the return system falls below the minimum setting. The pump should be operated at this position for normal and heavy duty.

(3) *"Float only."* The pump is governed by the float switch only and the pump operates when return condensate in the receiver rises above high water level. Operation is independent of the

vacuum control switch. Do not operate the pump at this position unless condensate flows into the pump receiver by gravity. This position is used:

(a) When shutting down steam.

(b) For night operation.

(c) Where service is light as when the system is tight enough to hold sufficient vacuum between float actuated operations, or when excessive piping leaks cause difficulty in maintenance of vacuum.

4-29. Maintenance.

a. Lubrication. Lubricate the motor and pump at regular intervals as indicated by lubrication instructions.

b. General cleanliness. Keep the interior and exterior of the motor and controls free from moisture, oil, and dirt. Blow out their interiors using a bellows when necessary. When switch contacts show signs of wear or pitting they should be smoothed, resurfaced and treated with a contact preservative. Replace contacts which cannot be smoothed.

c. Packing boxes. Give packing boxes the same care given those in any ordinary water pump. No vacuum is exerted on the packing boxes and they rarely require repacking. Observe the packing glands occasionally for leakage. A slight "weep" of water or about 30 drops per minute from the glands while the pump is in operation keeps packing in good condition. If serious leakage is noted, tighten the glandnuts evenly a few turns only. Do not draw glands too tight. After adjusting the packing glands, turn the shaft by hand to be sure it rotates freely. If serious leakage will not stop, see manufacturer's instructions for packing renewal.

d. Periodic inspection. For efficient operation, inspect the pump periodically as recommended by manufacturer's instructions.

(1) Check the automatic controls. See that the pump responds to vacuum and float switches properly.

(2) See that the motor comes up to speed quickly and maintains a constant rotation rate. If the motor is a brush type, see that it does not spark profusely while starting or running.

(3) The quickest and most effective test of the pump is to shut the condensate return valve, run the pump on float and vacuum control, and check the time requirement for the pump to attain a vacuum which it can hold. If the pump performs satisfactorily with the condensate return valve open, the trouble lies in the system, not in the pump.

(4) Check stuffing boxes for proper packing weep as described.

(5) Remove receiver handhole cover to inspect receiver tank. Flush out sediment.

4-30. Typical operating difficulties.

a. If pump will not run with selector switch at the "continuous" position:

(1) See if motor disconnect switch is open.

(2) See if fuse is loose or blown out and whether thermal units are tripped or simply not set.

(3) Check wiring for broken terminal connections or improper hookup.

(4) Check motor to see if it is burned out or shorted. If the motor is a brush type, see if a brush is worn or stuck.

(5) See if pump shaft is stuck. Try turning shaft by hand.

b. If pump will not run with selector switch in "Float Only" position when receiver is full of water:

(1) See if float is stuck or waterlogged.

(2) Check float switch contacts for corrosion or pitting.

(3) Check float control mechanism. See that adjustment is correct and that all keys or pins are in place.

(4) Check wiring to float switch.

c. If pump will not run with selector switch at "Float and Vacuum" position when vacuum is below set minimum and receiver is empty:

(1) See if vacuum switch contacts are corroded or pitted.

(2) See if vacuum switch regulation is correct.

(3) Check wiring to the vacuum switch.

d. If fuses blow out or thermal units trip:

(1) Check fuse or thermal unit rating used.

(2) See if fuse location is too hot. Boiler room temperature may be high.

(3) Turn the pump shaft by hand to see that it is free. Sticking may be caused by glands which are unevenly or too tightly adjusted, clogging or pump, extreme wear of pump or motor bearings, or rubbing of impeller or rotor within the pump due to improper clearance adjustments.

(4) Check wiring. Test for loose connection or short circuit.

(5) See that the motor is not grounded or partially burned out.

(6) See that switch contacts are not worn or arcing.

(7) Check brushes, when present, for excessive sparking while running or starting, or for sticking. See if commutator is dirty or scored.

(8) See if the motor is overloading.

e. If the pump runs continuously, turn the selector switch to "Float Only Position". If pump continues to run:

(1) Check float control mechanism for stuck float.

(2) See if excessive condensate is returning to the pump as during morning heat up or when shutting down steam.

(3) Check float switch contacts for burning.

(4) See that accumulated sediment in the receiver tank is not holding the float up.

f. If the pump runs continuously, turn selector switch to "Float and Vacuum position". Continuous pump operation on vacuum control is usually caused by excessive air leaking into the system (leaky flanges, broken fittings, defective valves and packings, etc.), by excessive condensate temperature (due to leaking traps, etc.), by a defective control element, or by inadequate pump capacity. If the pump continues to run:

(1) Check vacuum switch contacts for burning or pitting.

(2) See if there is a vacuum, or practically no steam pressure present.

(3) See that the vacuum breaker valve is not opening below the minimum setting of vacuum switch.

(4) Check piping connections to the vacuum switch. Be sure this line is open and unobstructed.

g. If the pump does not produce or maintain a vacuum with valves in condensate return line closed:

(1) See if prime water has been lost.

(2) Test air-relief check valve and inlet check valve for leakage.

(3) Replace worn or deteriorated discs.

(4) Inspect the pump thoroughly for gasket leaks.

(5) Check the packing nut on float control for leakage

(6) Check motor rotation direction and speed, and supply voltage.

(7) See if the condensate is so hot that it flashes into steam under vacuum. If so, the traps in the system are allowing steam to pass. When this condition is very bad, a slight pressure is sometimes indicated on the combination gauge. Steam is sometimes seen pouring out of the air vent and the pump casing is very hot to the touch.

(8) Check for air leaks in the receiver tank or manifold as at plugs and casting holes.

(9) Inspect for clogged inlet strainer or clogged lift pipe.

(10) Check pump discharge pressure. The pump impeller may be clogged or worn.

h. If the pump does not produce or maintain a vacuum with condensate return valves open but does so with valves closed:

(1) Check the system for leaky or ineffective traps or for a branch where traps were not installed.

(2) Check the system for leaks in the return line as from an open pipe end or loose connection.

(3) Test check valves in the equalizer line between the steam main and condensate return line, and in the bypass between the boiler return line and the condensate pump.

(4) Be sure that the heating system is not banked or operating with low firing. This will allow traps to stay open so that no vacuum can be created in the return system.

i. If the pump loses its prime:

(1) Test the inlet check valve for leakage. For rapid test of the valve, break vacuum by tripping the vacuum breaker valve manually, remove the strainer handhole cover, prime the pump, and observe whether prime water is leaking through.

(2) Look for simultaneous leakage of check valves on the air vent line and in the bypass between the condensate return and boiler return lines. Loss of prime from this leakage usually occurs at night or during a low-fire period.

(3) See that the packing boxes are not leaking excessively.

(4) See that the casing drain plugs are not out or loose.

j. If water floods over the vent line when the pump is not in operation:

(1) Be sure switches are set for operation so that pump can run.

(2) Be sure a Hartford Loop has been used and that the air vent line has been run as high as possible.

(3) See that the float-control mechanism is operating and that the pump responds to float switch.

(4) See if the check valve in the discharge line to the boiler is leaking or installed backwards.

k. If water floods over the vent line when the pump is in operation:

(1) See that the check valve in the boiler return line is not stuck, or closed, or installed backwards. Be sure the boiler return line is not clogged.

(2) Be sure the pump is returning water to the boiler. Check pump rating and the discharge pressure, and compare with the existing discharge head.

(3) Inspect vent strainer to see that it is not dirty or greasy allowing pressure to build up in the hurling chamber and preventing separation of vapor and water.

(4) If flooding occurs when the pump is first started as at the start of the morning heat up, see if condensate has been trapped or accumulated in quantity within the return piping and receiver. By running the pump at Float Only control at night, this is avoided.

(5) See if the lift pipe is clogged at the bottom. Be sure sediment has not accumulated in the receiver tank.

l. If operation of pump is noisy:

(1) See if prime water is lost or if the pump is flashing steam.

(2) See if the pump is operating at a high vacuum.

(3) See if the inlet strainer is clogged.

(4) See if the lift pipe is clogged.

(5) Check installation for pipe strains, poor anchorage, or improper alignment of pump motor shafts.

(6) Check bearings for wear or deterioration.

(7) Check whether receiver is flooded. Also check the float switch adjustment. See if the float switch adjustment is improperly regulated allowing the receiver to overfill flooding the lift pipe.

(8) Inspect the hurling water chamber, inside casing, for flooding due to a leaky boiler feed check valve which creates pressure in hurling water chamber.

(9) See whether the air vent strainer is clogged allowing pressure to build up in the hurling water chamber.

(10) See if noise occurs at a time of rapid acceleration of the motor with the receiver under a high vacuum.

(11) See if noise is the result of amplification due to resonance within the building or pump room.

(12) See that the pump is set level. If the pump is not level, the sleeve bearing motor shaft will rock back and forth.

(13) Observe if there is foaming in the hurling water chamber caused by oil from steam engine exhausts or excessive use of boiler compounds.

Section VII. WATER LEVEL REGULATORS AND CONTROLS

4-31. General.

Water level regulators and similar equipment controls such as pump operation controls, consist basically of an enclosed float actuated valve, a switch, or a combination of both, mounted on the outside of the boiler to maintain a safe boiler water level. Regulators are arranged to serve some or all of the following purposes or combination of purposes:

a. Maintenance of minimum water level by cut-in of float actuated cold water make up.

b. Elimination of excessively high water level by opening of the float actuated overflow.

c. Maintenance of normal water level by cut-in and cut-out of the pump motor through float-actuated switch.

d. Stopping automatic stoker, oil burner, or gas burner by float actuated switch when water level is low.

4-32. Installation.

A satisfactory water level regulator installation for a conventional steam heating system consists of a mechanical boiler water feeder to maintain a minimum water level and an electrical low water cutoff to stop the boiler's automatic firing devices in the event of a low water condition. The unit is mounted at the low safe water level of the boiler. Since most manufacturers clearly mark the regulator body to indicate the water level maintained by the unit, the unit is normally installed below the normal operating level of the boiler in such a manner that the water line mark on the regulator body coincides with the low safe water level in the boiler. This is shown in figure 4-20. In addition to the combination feeder cutoff shown, steam boilers require a second low water cutoff independent of the first, with its own set of drum connections for blowdown valving and piping.

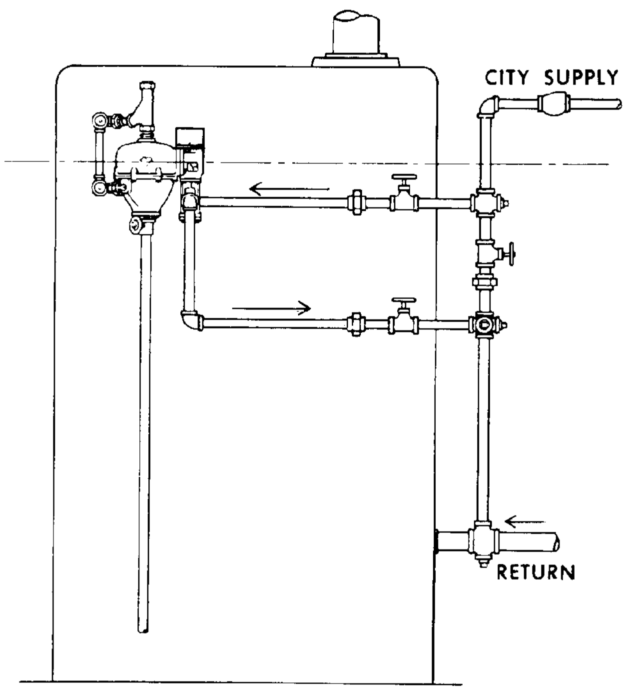


Figure 4-20. Water level regulator connections.

4-33. Initial operation and servicing.

a. The mechanical feeder maintains a safe minimum boiler water level, as recommended by the boiler manufacturer. In an emergency situation where boiler level drops approximately ¾ inch below the safe minimum level, the electrical low water cutoff switch stops the boiler's automatic firing equipment. When boiler water level is restored to ½ inch above the emergency low water level, the cutoff switch restarts the automatic firing equipment and control is returned to the mechanical feeder. Water level controls and similar devices are installed so that the exact operating characteristics and setting locations of the equipment for the purpose intended by the manufacturer are obtained. Maintenance of the boiler water level with regulators depends upon the carrying of a correct and stable water level in the float control unit. The unit is connected so that internal circulation of the boiler steam and water flow will not cause a false or fluctuating water level in the float body.

b. After prolonged shut down, fill boiler to within 6 inches of normal water level. Open feeder connections and note the rise of the water level and shut-off level of the feeder. The shutoff level of the feeder should be at the low safe boiler water level. Fill the boiler to the normal level plus enough water to fill the system with steam. For a quick check of the feeder, open the feeder drain valve for a few seconds. If the feeder is in proper operating condition, flow of makeup water should be immediately observed.

4-34. Operation and maintenance.

Clean and blow off dirt and scale in feeders as required by manufacturer's instructions or if required by poor water condition. To blow down units, close valves in the top and bottom connections to the boiler and open the blowoff valve. Keep the blowoff valve open until the water flow is clear. Do not open the feeder or water line controller connections to a new boiler installation until the boiler and system have been thoroughly cleaned. It is also necessary to check electrical connections and float elements.

4-35. Typical operating difficulties.

A boiler can have too much or too little water for many reasons. If a boiler is equipped with an automatic boiler water feeder and water level is not maintained correctly, do not assume that the feeder is faulty. Figure 4-21 shows a typical cold-water piping hook-up to the feed valve of a boiler-water feeder. Follow the procedure below if the boiler water level cannot be maintained.

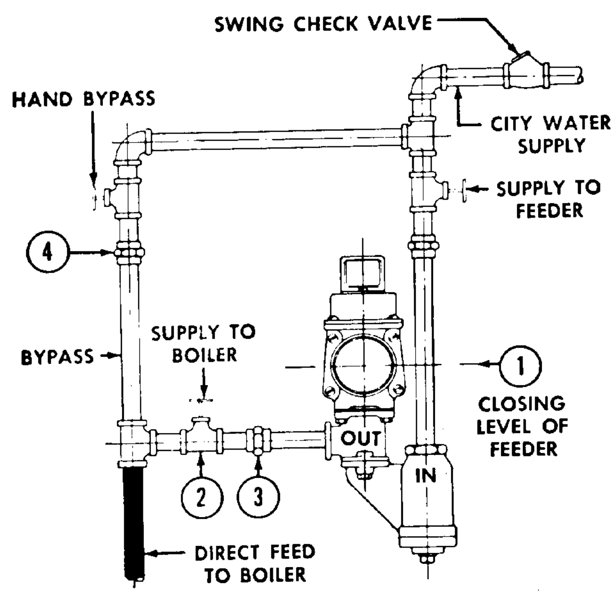


Figure 4-21. Boiler water feeder piping connections.

a. Make a broken union test for checking feeder operation.

(1) Make sure water in the boiler is above the closing level of the feeder.

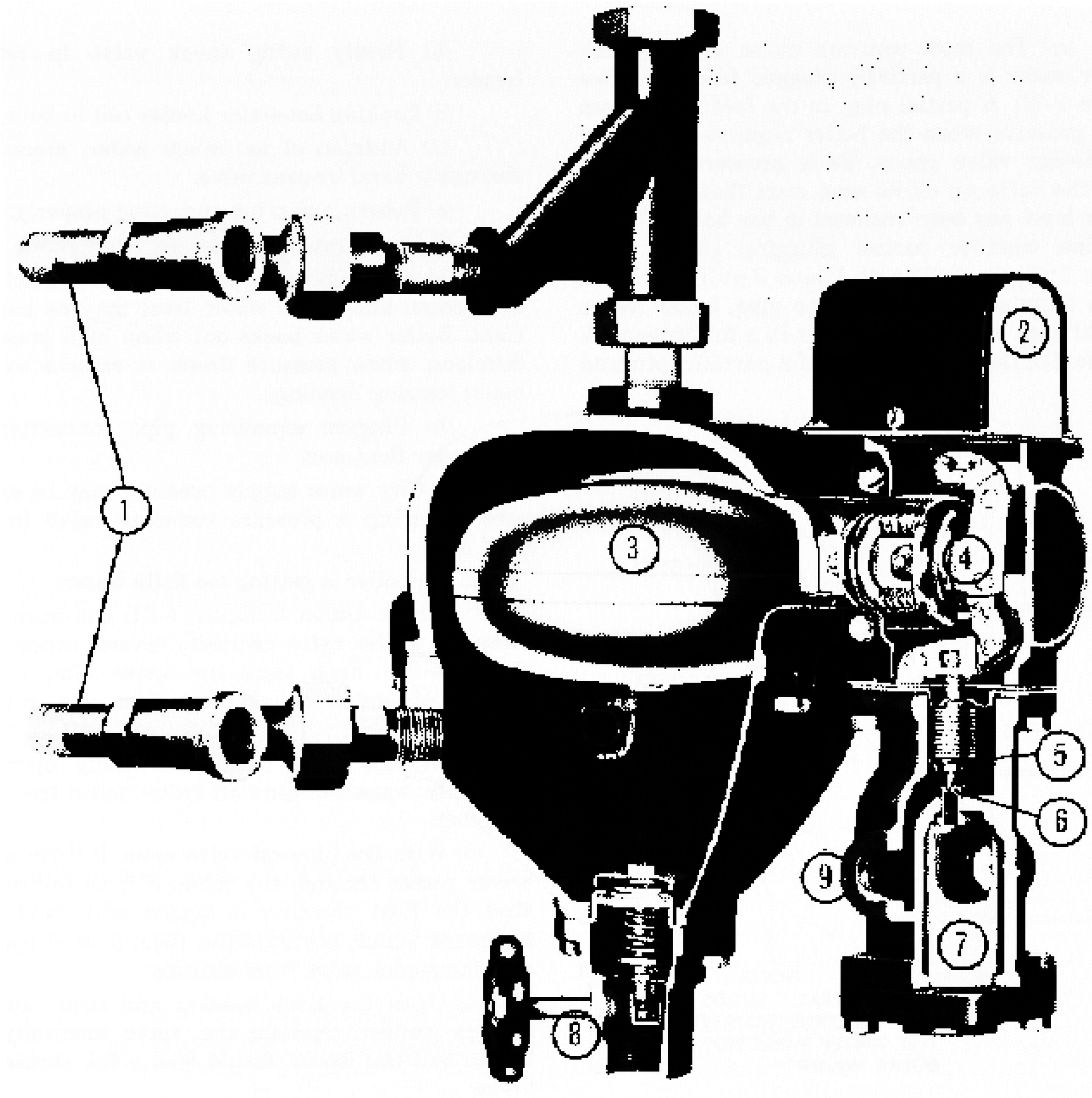
(2) Close Valve 2 (figure 4-21) in the direct feed pipe from the feeder to the boiler.

(3) Break Union 3 between the feeder and Valve 2.

b. Check to see if the boiler is getting too much water.

(1) If water trickles out of the broken union from the feeder valve:

(a) Open and close the water feeder valve manually several times. (See figure 4-22.) This should remove any obstruction from the water feeder valve seat, and the valve should drive itself to a driptight closure.



1. CONNECTIONS TO BOILER
2. ELECTRICAL CUT-OFF SWITCH
3. FLOAT
4. SYLPHON ASSEMBLY
5. WATER FEEDER VALVE DISC
6. WATER FEEDER VALVE SEAT
7. STRAINER BASKET ASSEMBLY
8. BLOW-OFF VALVE
9. BOILER WATER SUPPLY OUTLET

Figure 4-22. Boiler water feeder details.

(b) If manual operation of the valve does not eliminate leaking, remove and repair the valve or return the valve assembly to the manufacturer for replacement.

(2) If no water trickles from the broken union, the feeder operation is not the cause of flooding and a further check must be made to trace trouble.

(a) The most common cause of too much boiler water is a partially plugged feed line. (See figure 4-23). A partial plug in the feed line causes back pressure when the boiler requires water and the feeder valve opens. Back pressure tends to hold the valve up off its seat, even though normal water level has been restored in the boiler. To determine whether partial plugging exists, open Valve 2 (figure 4-21) with Union 3 still broken. If there is no swing check in the pipe, boiler water should back out from the boiler in a full stream. A trickle-like flow will be proof of a partially plugged pipe.

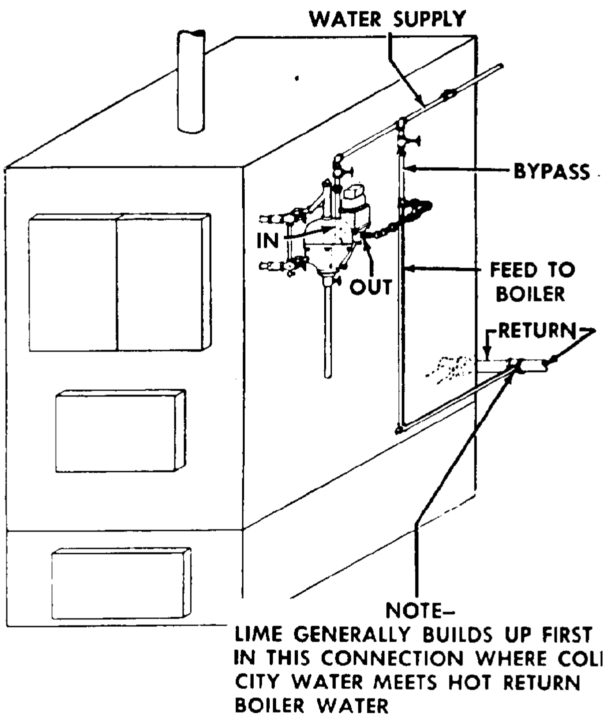


Figure 4-23. Stoppage area in boiler connection.

(b) Another common cause of flooding is a leaky hand bypass valve. Break Union 4 (figure 4-21) with the bypass valve closed. If water leaks out of the union, install a new globe valve.

(c) When boiler water feeders are piped up with 1 inch equalizing pipes, flooding of boiler may be caused by a faulty piping hook-up. Connecting the equalizing pipe from the bottom of the feeder chamber into the return header or bottom of boiler, or running a direct feed pipe into the equalizing line, will cause flooding.

(d) Closing level of the feeder on heating boilers should be set about 2 to 2½ inches below normal boiler water line.

(3) Other common causes of excessive boiler water are as follows:

(a) Dirty boiler water.

(b) Faulty swing check valve in return header.

(c) Leaking hot-water heater coil in boiler.

(d) Addition of too much water, manually, through a hand by-pass valve.

(e) Return pump not operating properly.

(f) Firing rate of burner set too high.

(g) The difference between the level of the dry return and boiler water level may be insufficient. Boiler water backs out when high pressure develops; when pressure drops, it returns to the boiler causing flooding.

(h) Plugged equalizing pipe connection to the feeder float unit.

(i) City water supply pressure may be excessive requiring a pressure reducing valve in the feed line.

c. If the boiler is getting too little water:

(1) Break Union 3 (figure 4-21) and open and close the feeder valve manually several times. (See figure 4-22.) Each time the valve lifts, a full stream of water should run from the broken union.

(2) If the valve cannot be easily operated manually, open the blow-off valve under the float chamber.

(3) With the blow-off valve open, if little or no water passes through the valve, it is an indication that the float chamber is loaded with mud and sediment which prevents the float from dropping and the feeder valve from opening.

(4) Open the float housing and clear out all foreign matter. Operate the valve manually as before and the feeder should feed a full stream of water.

(5) The broken union test may show that the feeder is in good condition but still does not feed water into the boiler. The feedline shown in figure 4-23 may be fully plugged, especially where the connection is made to the return header or bottom of the boiler.

(6) If little or no water comes through the feeder valve when operated manually, remove and clean out the strainer. The strainer may be filled with sediment which prevents water from getting to the feeder.

(7) Other common causes for insufficient water in the boiler are:

(a) Priming and foaming due to dirty boiler water.

(b) Excessive pressure difference between supply and return piping preventing condensate return to boiler.

(c) Faulty operation of the boiler feed pumps.

(d) City water pressure less than boiler steam pressure.

Section VIII. BOILER TRIMMINGS, GAUGES AND POP SAFETY VALVES

4-36. General.

Many newly installed glasses are broken by turning water onto them carelessly. A piece of screen mesh or canvas may be used as protection against breaking glass. For installing and replacing glasses the following suggestions are considered good practice.

4-37. Gauge glass breakage.

A brittle and improperly cooled glass breaks easily. Purchase only the best glass. Long glasses break easily; glasses no longer than 12 inches are preferable.

4-38. Installing gauge glasses.

a. Fuse cut ends since glasses are weakened by broken surfaces.

b. Place glass connections in perfect alignment and free from strain on glasses. Jamming or twisting glasses when tightening the stuffing box nuts causes breakage.

c. Gauge glasses are broken easily if scratched. Exercise great care in storing.

d. Gauge glasses should be protected from an accidental blows. Provide rods or other means of guarding the glass.

e. Open and close all cocks slowly.

f. Wear goggles during this phase of installation. Remove all broken pieces. Open valves slowly and blow out any debris taking care to turn face away. Make sure new glass is of the proper length, that the drain is open and connections are lined up. Insert glass, but do not set up too tight. Replace the guard if cocks must be opened and closed near the position of the glass or cannot be operated from the floor.

g. Open the top valve slightly and warm glass by allowing a little steam to pass through so that heat is evenly distributed over the entire column. If water is admitted first, uneven heating may break the glass. When the water level appears steady, open the bottom valve wide and then open the top valve wide. Always test the water glass when replacement has been made. This should also be done when the boiler is placed in service and when difficulty is experienced with foaming or priming.

4-39. Testing and care.

Keep all lines and valves between the water column glass and the boiler clear. When it is difficult to read the level because of a foreign substance in the tube, replace the glass. Do not clean a glass while it is in place.

4-40. Steam pressure gauges.

a. Connect at least one gauge with gauge cock and siphon to each boiler and keep it in good condition to indicate steam pressures accurately.

b. Keep gauge dials and glass covers clean and well lit to permit easy reading at any time.

c. Test and reset pressure gauges as required by manufacturer's instructions or when readings appear abnormal.

d. Installation of suitable connections to each boiler for inserting a test gauge is of great assistance. Install a tee connection on the gauge line so that a standard test gauge may be used to check the condition of an indicating gauge.

e. Never admit steam directly to the gauge. If steam is admitted to the gauge, the gauge should be retested. Be sure the siphon is properly filled with water at all times.

f. Steam gauges on a battery of boilers should be graduated alike and should be of the same type.

4-41. Safety valves.

a. Never operate a boiler without one or more safety valves of sufficient capacity as indicated by the ASME Code. Keep those valves free and in working order at all times.

b. Never place a stop valve between the boiler and a safety valve.

c. Test the safety valve periodically by lifting the valve off of the seat by hand. This should not be done unless the boiler pressure is from 80 to 85 percent of the present popping point. Under no condition attempt to prevent safety valve leakage by tightening the spring.

d. When a safety valve does not pop at the required pressure, check carefully to determine the cause. If the faulty valve condition cannot be corrected, replace the valve.

e. Set safety valves in accordance with ASME Code requirements to pop at the proper pressure, blow to reduced pressure, and close without chattering or simmer. All safety valves should be properly sealed after being set.

4-42. Blow-down pipes.

Maintain all valves, cocks, and lines carefully and inspect regularly for defects. Where leaks are discovered, make repairs as soon as practicable. Examine discharge end of blowoff pipes for indication of leaky valves. Discharge ends of blowdowns should be open for inspection at all times.

4-43. Dampers.

Inspect all dampers for looseness and other defects before boiler is placed in service. Examine dampers periodically and keep in good condition.

Section IX. TRAPS

4-44. General.

The basic purpose of a trap is to discharge condensate, entrained air, and other gases from a steam area, while preventing or minimizing loss of steam. Various types of traps in use are: bucket, thermostatic, combination float and thermostatic, and thermodynamic traps. For steam heating systems, the thermostatic, or combination float and thermostatic (F&T) are most commonly used.

4-45. Thermostatic traps.

Thermostatic traps are varied in design detail but are classified as bellows or diaphragm type based on the kind of expansion element used. (See figures 4-24 and 4-25).

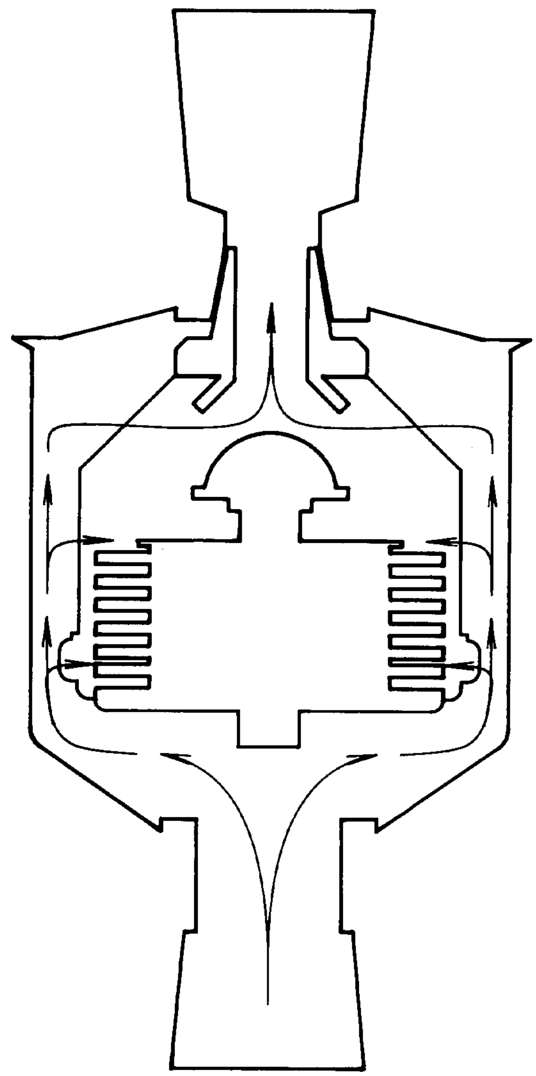


Figure 4-24. Thermostatic trap (bellows type).